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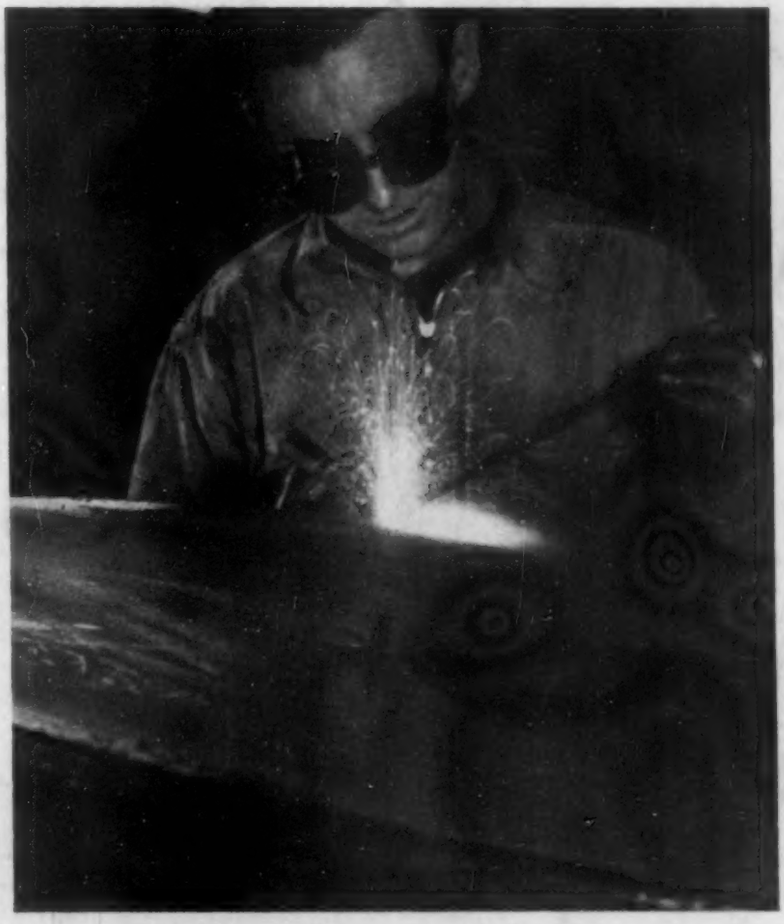

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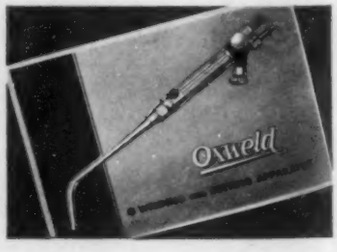

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THE
AMERICAN WELDING SOCIETY
JOURNAL

WM. SPRARAGEN, Editor | VOL. 14 | NO. 3

MARCH

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A "Flying Wing"

Unique Flying Machine Designed Specifically for Greater Safety Completely Oxyacetylene Welded

By OWEN C. JONES*

FLYING, perhaps man's greatest achievement, will always hold tremendous fascination to the layman until possibly the use of aircraft becomes as common as that of the automobile. As long as the use and operation of aircraft is limited to a relatively few individuals, this fascination will be intermixed to a certain extent with wonder and speculation regarding the strength and endurance of the materials and joining methods used in plane fabrication. To those well versed in the lore and technique of flying it is well known that knowledge of the strength of materials has been one of the great factors that has made possible the remarkable safety records of the heavier-than-air craft; and it is of considerable interest that the oxyacetylene process still maintains a predominant position in the aircraft manufacturing field for the joining of metal parts.

In the earlier days of the flying age a successful salesman of flying machines became specially interested in the problem of providing maximum safety for the purchaser of a plane. Not that the machines he sold were of faulty construction, because they were, as a matter of fact, as good a piece of equipment as the then available knowledge of aerodynamics, materials and fabrication processes combined could make them.

His enthusiasm for this phase of the subject eventually led him to start developing some ideas of his own. His interest lay with making flying as safe as possible to the individual owner of a small machine and this brought with it the need of developing a machine inexpensive enough and still safe enough for the layman to want to own and operate. He felt then, and feels today, that there is a great future for the small flying machine.

It was, therefore, with considerable elation that he saw his successful and rather radical design create considerable interest and speculation when it was first officially presented to public gaze at the International Aircraft Show in 1933. Further flying tests suggested certain further improvements so that the machine shown in the accompanying photographs represents the latest refined design in this unusual "flying wing." The model shown is a two-seater, 70 hp., with a 17-ft. wing span and (our information is not exact on this point) about a 14-ft. chord. The chord is the distance from front to rear edge of the wing. This makes the aspect ratio (ratio of wing span to chord) extremely low and is the dominant feature of the ship. Other than this there are the usual ailerons, elevators and rudder.

The plane is capable of doing 110 m.p.h. and, due to the unusual aspect ratio, has a landing speed of only 11 ft. per sec. This is doubly interesting in the light of the recent Federal Government specifications for

* Technical Publicity Dept., Linde Air Products Co.

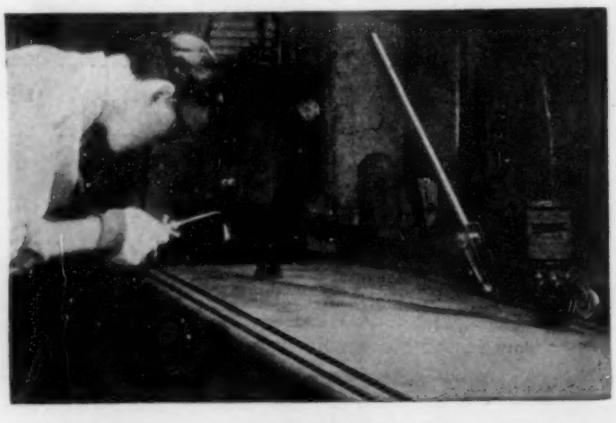
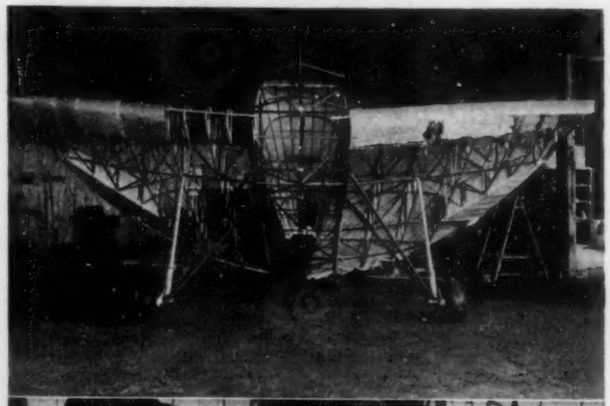


Fig. 1—In Fabricating the Control Mast Both Steel and Bronze Welds Assure Strength and Endurance

Fig. 2—There Are 19 Steel Welds on This Emergency Door Frame



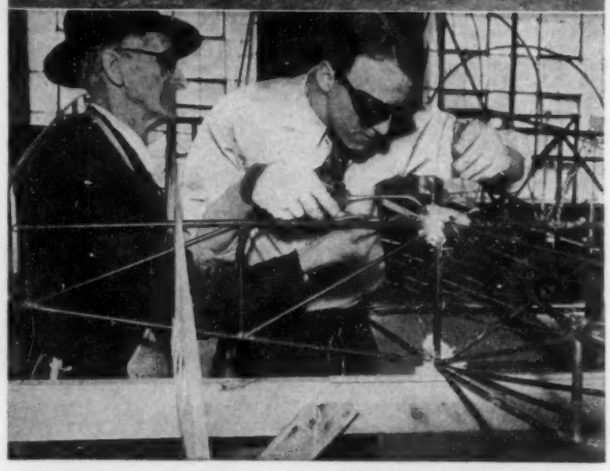


Fig. 3—There Are 75 Steel Welds and 15 Bronze Welds in This Tail Group Assembly

Fig. 4—The Sturdy Construction of the Welded Plane Is Clearly Visible

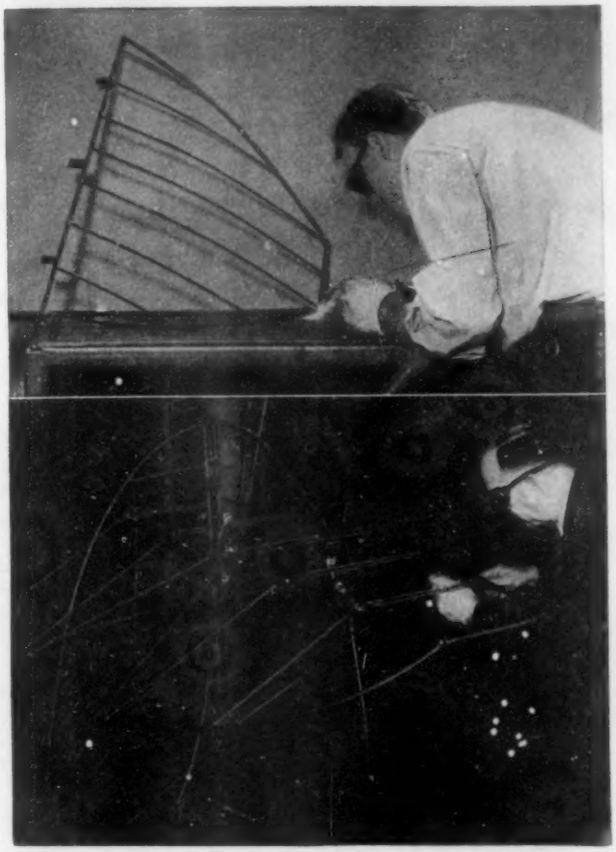


Fig. 5—A Spar Member Is Being Joined to Main Body. Observe the Use of Wet Asbestos Fiber for Protecting Adjacent Parts from Excess Heat

light, safe but slow landing moderate-priced plane which were given out recently in connection with a program for the development of such machines. These called for a minimum of 25 ft. per sec. landing speed. The weight of the ship empty is 500 lb., loaded with two passengers, about 1065 lb.

The construction features of this craft are worth consideration inasmuch as the designer's interest was in quality and safe fabrication as well as performance. He made a most conscientious effort to select the best grade of chrome-molybdenum tubing and sheet as well as other parts and materials going into the plane. He even went further by carefully investigating the performance of the apparatus and supplies used in the fabrication work.

Welding rod, apparatus, supplies and gases were given special attention. Several months alone were spent investigating the merits of various types of welding apparatus, and the uniformity and quality of welding rod; and exacting tests were made for strength, ductility and ease of welding.

High-test steel rod was standardized on for joints on the main body of the fuselage. A good grade of drawn iron rod was selected for the lighter members of the wings and tail structure. The well-known, high-strength bronze rod was chosen for joining washers to parent metal to increase thickness when a bearing surface was required. It was also used for joining the rear cowling ring to the engine support. The front cowling ring was bolted to the engine but the many supports that braced it were all bronze-welded.

The main fuselage of this plane is similar in most respects to that of other aircraft, but rapidly changes form as the circular wings are added. The chrome-molybdenum tubing used is as light-walled as possible, 0.035 in. thick. Likewise the chrome sheet used was 0.035 in. thick except in a few cases for special fittings where it was 0.049 and 0.065 in.

More detailed explanation of the accompanying illustrations will give some interesting side-lights on the work.

In Fig. 1 the operator is using the drawn iron rod for welding the control mast to the control unit. The small washers on the mast (just above the blowpipe tip) have been bronze-welded on to provide a greater bearing surface. This interesting control unit allows the control cable to hook on to the bottom of the stick from which it runs over the pulley and returns through the aileron control torque tube.

The operator shown in Fig. 2 is completing work on the emergency door frame. There are 19 welds on this frame all made with drawn iron rod.

Figure 3 shows the tail group assembly. This has no less than 75 steel welds made with drawn iron rod and 15 bronze welds where washers are joined to the tubing for the purpose of increasing the tubing thickness where greater bearing surface is needed. Some of the bronze welds can be detected by their light color. The operator is making another such joint.

A view of the under side of the ship is shown in Fig. 4. Its unique shape is easily seen, and its sturdy build, with additional strength supplied by the extensive area of wing spread, is clearly visible. Hundreds of welds, carefully made by competent operators, assure strength.

Additional interest lies in the fact that the engine support and braking devices, though not illustrated here, are fabricated with high-test steel rod.

The illustration, Fig. 5, shows a spar member being welded to the main body structure. Spar fittings, two of which can be seen at the extreme left end of the structure, are fabricated from tubing and are held in place securely by a strap of chrome-molybdenum sheet that is welded to the tubes. Drawn iron welding rod is used for this application. The hooks and turn-buckles which are a part of this assembly are not shown but they are welded to the tubing in the same way. Observe the clips welded to the cabin framework (look on the section of tubing that runs down and behind the operator's head). These are all bronze-welded and are for the purpose of holding the wooden framing for the false structure for streamlining the cabin.

Figure 6 shows the first experimental plane in the air. A picture of the completed plane containing the improvements is not available at this time but the general form is almost identical.

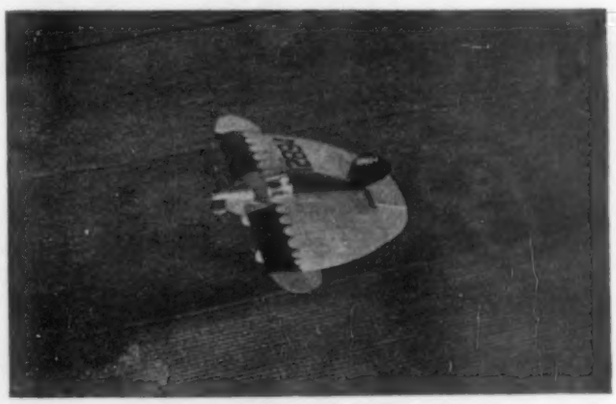


Fig. 6—The "Flying Wing" in the Air. It Has a Top Speed of 110 M.p.h. and a Landing Speed of 11 Ft. per Sec.

Physical Properties of Fusion-Welded Joints

As Produced by Manufacturers of Class I Pressure Vessels*

By R. K. HOPKINS

FUSION welding of metals by oxyacetylene and by the electric arc methods has been done for a great many years, both in this country and abroad, but it is only within the past 5 or 6 years that it has been perfected to the point where the properties of the welded joints could be considered equal to those of the plate materials. This has been brought about primarily by the development of the covered electrode used in electric arc welding. Great strides have also been made in the advancement of gas welding, but since the purpose of this paper is to describe briefly the physical properties obtained today by the leading pressure vessel fabricators in this country, all of whom use the electric arc, I shall confine my remarks to this latter process. Thousands of tons of pressure vessels and piping have been successfully fabricated by arc welding using the covered electrode. By far the largest percentage of this tonnage is of plain carbon steel, but a considerable amount of alloy steel of various analyses has also been satisfactorily welded.

It has been my privilege in the last few months to contact the leading fabricators of Class I pressure vessels in the U. S., with the idea of getting from each the maximum, minimum and average values of the physical properties obtained by them in welded joints on regular

* This paper was presented by R. K. Hopkins, Director Metallurgical Research, of the M. W. Kellogg Company, at the Joint Meeting of the A.S.M.E. and AMERICAN WELDING SOCIETY on Monday, January 14, 1935.

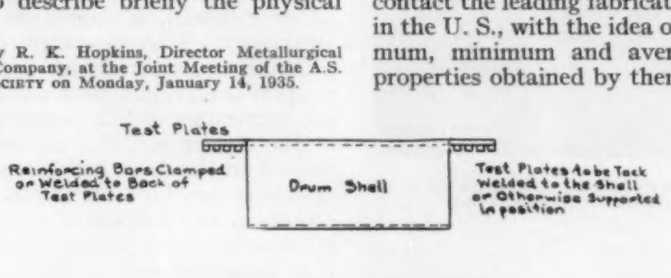

Test Plates
Reinforcing Bars Clamped or Welded to Back of Test Plates
Drum Shell
Test Plates to be Tack Welded to the Shell or Otherwise Supported in position
Test Plate
Test Plate
Reinforcing Bars
Shell
Double Welded Butt Joint Shall be used
Shell

Fig. U-9

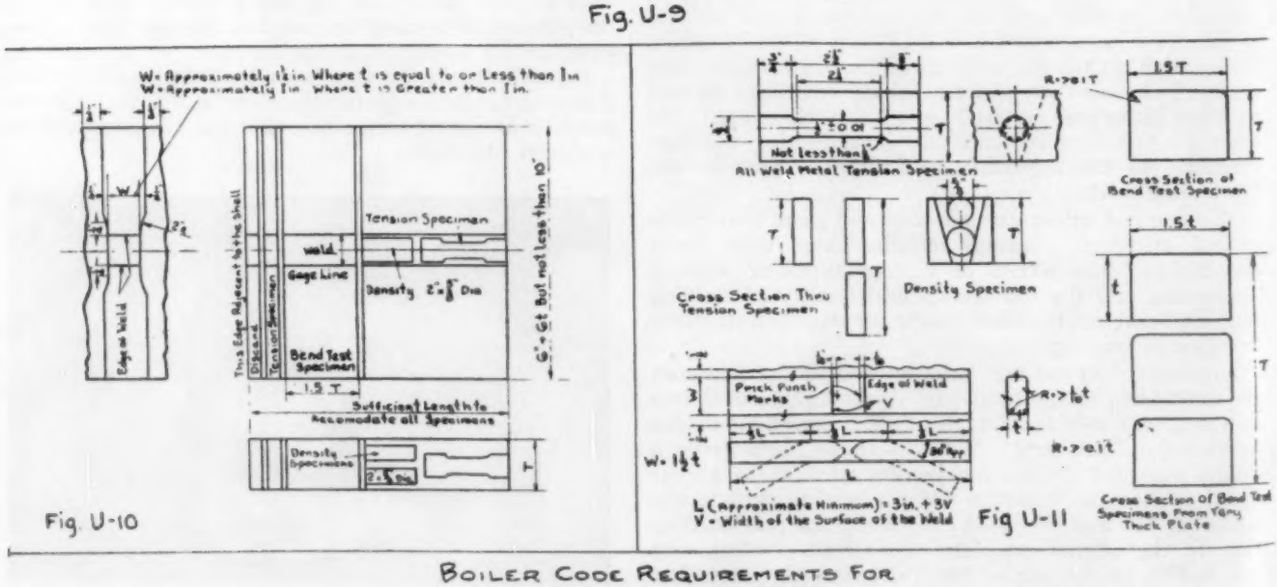

W = Approximately 1½ in. Where t is equal to or Less than 1 in.
W = Approximately 1 in. Where t is Greater than 1 in.
Tension Specimen
Weld
Gage Line
Density 2"x⅜" Dia
Bend Test Specimen
1.5 T
Sufficient Length to Accomodate all Specimens
Density Specimens
Edge of Weld
Punch Punch Marks
Edge of Weld
V
W = 1½ t
L (Approximate Minimum) = 3 in. + 3V
V = Width of the Surface of the Weld
All Weld Metal Tension Specimen
Not less than ¾
Cross Section Thru Tension Specimen
Density Specimen
Cross Section of Bend Test Specimen
1.5 t
Cross Section Of Bend Test Specimens From Very Thick Plate

Fig. U-10 Fig U-11

BOILER CODE REQUIREMENTS FOR CLASS I TEST PIECES

Fig. 1

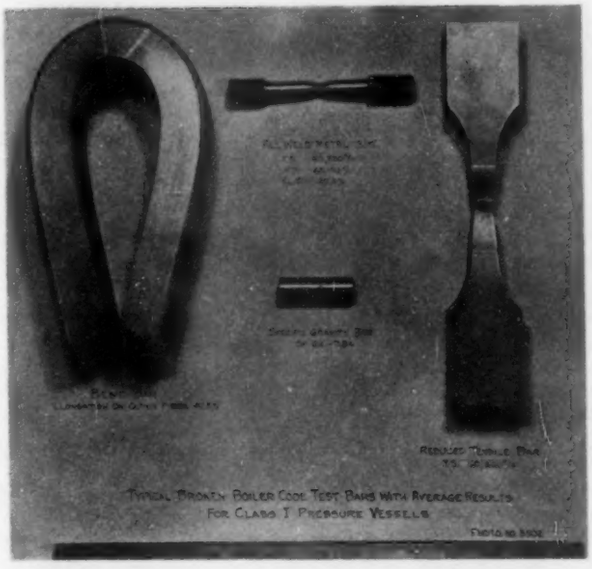


Fig. 2

production work. At the request of the Class I Welding Association (an organization made up of practically every accredited welding fabricator of pressure vessels in this country), this data has been correlated and will be presented for the benefit of those interested in the quality of welds obtainable today.

Before presenting this data, it would probably be well to explain briefly the requirements of the Boiler Code for the physical tests which must be met for each Class I pressure vessel produced. In order to make this explanation a little clearer, the following illustrations are offered.

Figure 1 shows Figs. U-9, U-10 and U-11 as presented in the latest edition of the Unfired Pressure Vessel Code, covering the test pieces required for Class I pressure vessels. Figure U-9 at the top shows how the test pieces are to be connected to the shell so that the welding of these pieces will be identical to that on the shell itself. The Code gives the fabricator the option of welding these plates separate from the tank, but prefers that they be welded as described above, where possible. After the welding has been completed, the pieces are cut from the end of the shell, the reinforcing bars removed from the back and the test pieces stress-relieved. Figure U-10 in the left-hand corner shows how the piece is laid out, so that the required test specimens may be taken from it. It will be noted that an all-weld-metal 0.505-in. tensile bar is taken from the weld itself, as is a standard $^{5}/_{8}$-in. diameter density bar. A bend piece is taken from across the weld, as well as a reduced tensile bar. As is evident, the 0.505-in. weld bar is required so that the physical properties of the weld metal itself may be determined. The density bar likewise is to determine the density of the weld metal itself. The bend bar shows not only the ductility of the outer fibers of the weld metal, but also the over-all ductility of the welded joint. The reduced tensile bar is designed in such a way that the maximum stress is thrown across the welded joint, so that any weakness either in weld metal or at the lines of fusion, or in the heat-affected area of the plate itself, will be detected. Figure U-11 in the lower right-hand corner shows in more detail the dimensions to which these test specimens are machined. In the case of very thick plate where it is not possible to test the bars of full thickness, the Code permits cutting the plate into two or more sections. These bars are taken in such a way, however, that the full depth of the weld is actually tested. I will not touch upon the X-ray requirements, or other tests, as these will be covered by one of the other speakers tonight.

Figure 2 has been prepared to show how the test pieces actually look after testing. The values shown under each of the test pieces are the average values as obtained by 5 of the leading welding fabricators in this country covering their entire experience since entering into the commercial production of Class I fusion-welded materials. These averages, therefore, represent the results of many thousands of tests. The values given, incidentally, are those obtained from welded joints in vessels made of 55,000-lb. minimum tensile strength plate.

Figure 3 has been prepared with the idea of condensing as much as possible the voluminous data collected from the various fabricators, covering the maximum, minimum and average values obtained in the physical tests conducted by them throughout their entire production experience of Class I welding. The values shown on these curves represent the average of those values presented by each company as obtained on the standard 0.505-in. all-weld-metal tensile bar. It will be noted that the average of the minimum values obtained for tensile strength are slightly above the minimum required by the code, namely 55,000 lb. per sq. in., whereas the average of the average values obtained by the various companies is well above the minimum requirement of the Code. This same statement can be made regarding the elongation in 2 in., for which the Code requires a minimum of 20%. The Boiler Code does not include a requirement for yield point of weld metal, but it will be noted from these curves that the ratio of yield point to tensile strength is well above that which is usually found in rolled or forged materials. This is a characteristic of weld metal as produced today, and is extraordinary when it is remembered that these unusually high yield points are accompanied by excellent ductility as shown by the elongation figures on this curve.

In all probability, this high yield point in weld metal will be taken advantage of in design at some future date. As a matter of fact, I happen to know that one of the largest welding fabricators in this country recently had

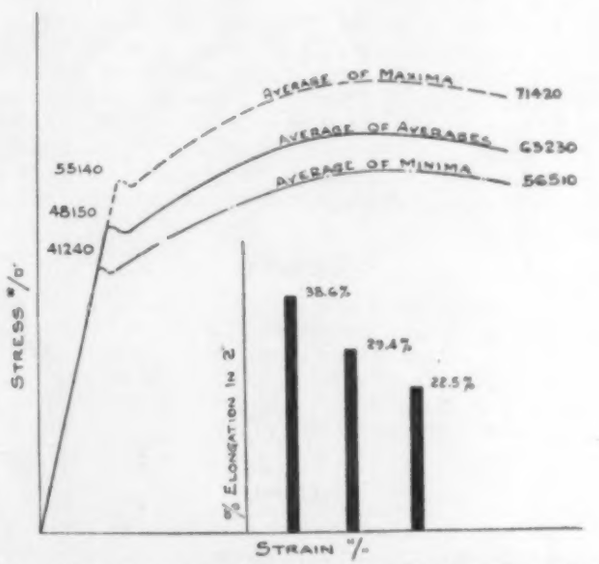


Fig. 3—Average Physical Properties of Carbon Steel Weld Metal as Determined by Thousands of 0.505 Tensile Bars Produced and Tested by Five Class I Welding Fabricators in the United States

occasion to design and quote on a high pressure penstock line for export. This line was designed on the basis of yield point rather than tensile strength, the customer having agreed to this method of design, even though the tensile strength of the weld metal was not quite as high as that of the plate. The reason the customer was agreeable to this design, and the reason the fabricator recommended it, was that it was felt that the higher ductility obtainable in the welded joint would produce a more satisfactory and safer job than if the design had been based on ultimate strength with its resultant lower ductility. In order to satisfy the company that such construction would be as claimed, the fabricator was required to ship several welded and unwelded test pieces to England for test. These tests were carried out in the Royal Naval College in Greenwich, England, by Prof. B. P. Haigh, who had been retained by the company building the penstock, to conduct these and other investigations. As a matter of interest, I will read excerpts from Prof. Haigh's report on these tests:

After describing the test pieces, which were of $\frac{1}{2}$ in. and 1 in. thick plates, Prof. Haigh goes on to state—

"In a letter received from the ..... Company, I was informed that the method of welding adopted is one of two methods regarded as satisfactory, and that it was adopted in consideration of the yield point rather than the ultimate being employed as the basis of design. The letter states that this method gives higher ductility at the expense of ultimate; and that another method gives higher ultimate at the expense of ductility.

They guarantee that the minimum yield strength of the weld will be at least 38,000 lb. per sq. in., but they explain that they are not prepared to guarantee that the breaking strength of the weld will be quite as high as 70,000 lb. per sq. in., which latter happens to be the breaking strength of the plates used, according to their statement.

"It is observed that the yield strength of the plates is decidedly higher than in any of the steels intended for gas-heated welding. (He refers to water-gas.) The high yield points were shown in a very clear way, preceded by somewhat higher primary yield points which could not be recorded with accuracy. The plates appear remarkably uniform from end to end, as is shown by yield spreading slowly and gradually without any change in the load.

"The yield points in the welded plates appear perceptibly although only slightly lower than in the unwelded: Thus the mean value falls from 53,800 to 51,100 lb. per sq. in. In the piece that was ground down to flush section, yield started in the plates and only later spread into the weld, which supports the maker's statement that the deposit is stronger than the plate in its yield point, although not in its ultimate tensile strength.

Ultimates

"The mean for the unwelded plates is 75,700 lb. per sq. in. The welded piece tested as received with weld 1.225 in. thickness had an ultimate of 71,100 lb. per sq. in., and the second welded piece, which we here had ground down flush to the plate, broke in the weld with ultimate of 69,000 lb. per sq. in.

Fractures

"All four, including the one that broke in the weld, are of excellent form and appearance with high reduction of cross section and every appearance of excellent ductility. The junctions between the deposit and the plate are only just visible even after fracture, and in the case of the piece that broke in the plate clear of the severely strained weld, the junctions are only just discernible.

NOTE: Although my long experience has been chiefly with welds that have NOT been normalized after welding, and only in the less degree with welds that have been normalized in a comparable manner, it may be of interest to add that I have not seen better welds than these, or any that gave such tensile strength in combination with such ductility and freedom from slag-inclusions or lack of fusion, etc."

I might say that these samples were not "normalized" in the true sense of the word, they having received a stress-relieving treatment at 1150° F. only.

It will be noted from an inspection of the present Boiler Code that there is no requirement for impact tests either on weld metal or on plate materials. These tests were omitted from the Code because it was proved at the outset that if the other test requirements are met, the impact properties of weld metal and adjacent areas in the plate will be satisfactory for operations at atmospheric and elevated temperatures. Table 1 has been prepared to give an idea of the impact resistance in various sections of the weld and adjacent areas, as well as that of the plate. It will be noted that the impact values of the weld metal and the adjacent areas are higher than those of the plate material. This is not always the case, but with properly made welds the impact values are invariably over 20 ft.-lb. It will be noted at the bottom of this table that the impact value of weld metal as produced by the bare-wire electrode is very low. This gives a good illustration of the effect the coating on a weldrod has on the physical properties of the weld metal.

Figure 4 shows pictorially what has just been shown in the above table. The type of impact bar used throughout this test is known as the 10/mm. Charpy keyhole notch bar. All tests were conducted at room temperature. The question of temperature at which impact tests are run, and also at which vessels operate, is a very important one. As stated before, the Boiler Code does not at present require that impact tests be made either on plate materials or weld metal. In order, however, to take care of those vessels which will operate at sub-zero temperatures, the Code will very probably

Table 1—Impact Resistance at Room Temperature of Weld Metal and Adjacent Areas

Mark	Location of Slot	Ft.-Lb. Charpy Keyhole	Average
CW	Center of weld	30.0 29.4 28.5	29.3
HW	Half way between center of weld and junction of weld and base metal	31.2 28.4 31.1	30.2
J	Junction of weld and base metal (refined zone)	28.5 33.7 31.7	31.3
A	Refined zone, base metal	35.5 40.6 33.0	36.4
AP	Zone where refinement of base metal commences	36.5 31.7 37.7	35.3
P	Original base metal	26.5 24.4 24.5	25.1

NOTE: Impact value of bare-wire weld metal varies between 2 and 9 ft.-lb.

have to make a revision covering such operating conditions. At present it only covers atmospheric and elevated temperature conditions, wherein the impact value of the materials is satisfactory. If, however, the temperature be lowered to below zero, the physical properties of certain materials change considerably. Carbon steel happens to be one of these materials, and it is a well-known fact that the impact value of this material drops very perceptibly when temperatures are lowered to zero and below. When such operating temperatures are encountered, it is necessary to resort to some alloy steel, or some form of special heat treatment which has proved itself suitable to produce a material whose impact resistance is consistently acceptable at the operating temperature. I wish to emphasize the word "consistent" because, although one set of bars may give excellent results, such as in carbon steel at low temperatures, the next dozen sets may be very poor. In the past two years, a considerable amount of work has been done on this subject to take care of certain oil and chemical plants which operate at sub-zero temperatures. Although no method has yet been developed which enables one to incorporate impact values as determined on a testing machine, in design it is safe to conclude that the impact test at least indicates the relative toughness between two or more metals. It is felt that serious consideration should be given this subject when choosing a material to operate at sub-zero temperatures.

Figure 5 shows the microstructure of weld metal and adjacent area. Attention is called to the extremely fine grain structure of the weld metal and adjacent area as compared to that of the plate material itself. Normally, the grain size in the weld metal is approximately one-fifth that of a hot-rolled carbon steel plate. It is

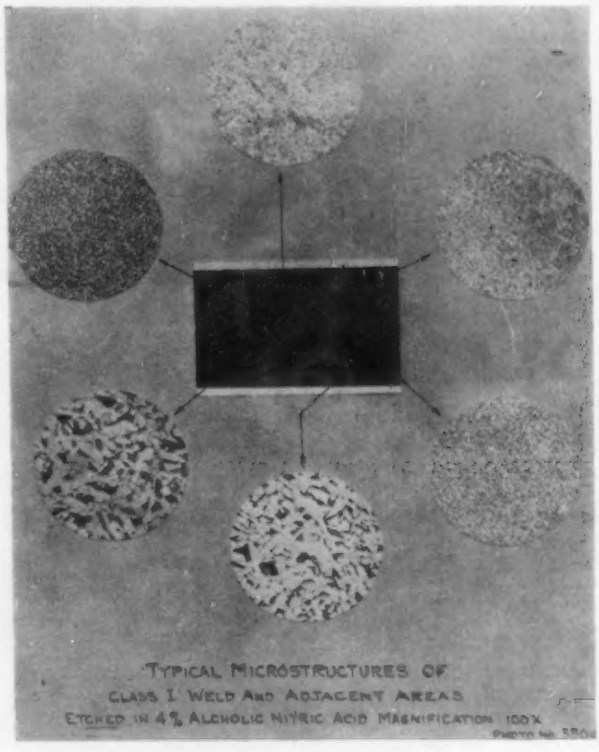


Fig. 5

felt that this fine grain size, coupled with the extreme purity of the weld metal, is responsible for the unusual physical characteristics displayed by it. You will recall from the previous figure that the impact value of the weld metal and adjacent area was higher than that of the plate. This, it is felt, is due to the small grain size of these two areas. It is interesting to note that the effect of grain size on impact resistance is even more pronounced in low temperature testing than when testing at room or elevated temperatures. When the grain size is kept small enough, even in carbon steel, the impact value can be held up to an acceptable figure at temperatures as low as —40° F. It has been found extremely difficult, however, to obtain a small enough grain in carbon steel to insure consistently good impact values at sub-zero temperatures. The tendency is to obtain extremely erratic results. For this reason it is felt, at least for the present, that alloy steels should be resorted to.

The question of fatigue strength of weld metal has not yet been mentioned, but it can be stated that this property is normal, that is, the fatigue limit is approximately one-half the tensile strength.

On account of the great variety of alloy steels which has been welded by the various fabricators, I will not attempt to present even a condensed set of data on physical properties of these materials. I can, however, make this statement, that with only a few exceptions, practically all of the commonly known S.A.E. alloy steels, and most of the stainless and corrosion-resistant steels, can be and have been satisfactorily welded, a considerable tonnage of welded corrosion-resistant alloy steel having been furnished the chemical and oil refining industries in the past few years.

In closing, I wish to state that it is my honest belief that with the proper choice of weldrod, welding technique and heat-treatment, practically any type of structure can be satisfactorily welded.

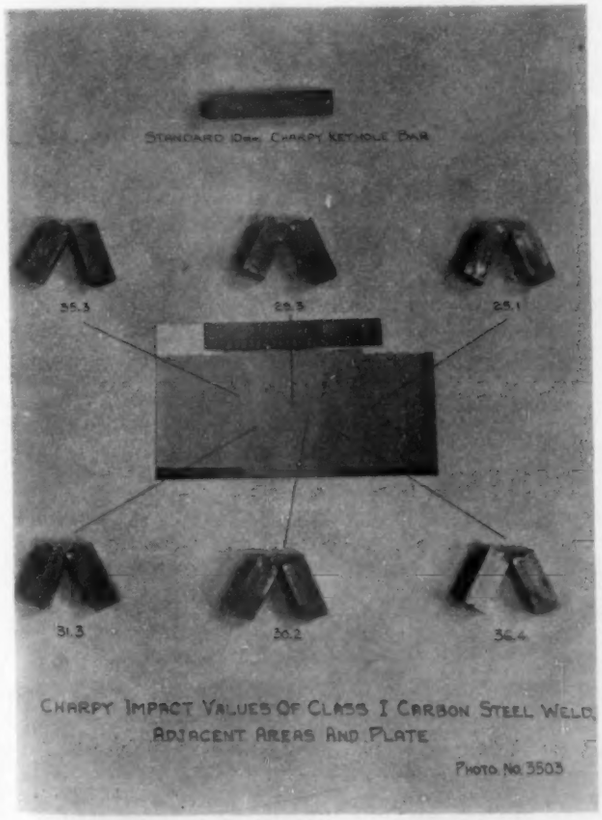


Fig. 4

Welding in Construction Work

By A. F. DAVIS†

All-Welded Penstock Successfully Completed

The Chicago Bridge and Iron Works recently completed the construction of two large penstocks for the Norris Dam of the Tennessee Valley Authority project. These steel penstocks are 20 ft. in diameter and vary in thickness from $1^1/_8$ to $1^3/_8$ in. The Electronic Tornado system of welding was used for the part of the work which was automatically welded. This system utilizes a magnetically controlled carbon arc which, combined with the proper flux, gives weld metal of the quality required by A. S. M. E. Class 1 welding specifications under which the work was done. After sections of pipe had been fabricated by automatic welding, they were transported to their place in the dam and joined together by manual shielded-arc welding.

Norris Dam, first of six in the huge TVA development, is located about 25 miles northwest of Knoxville, Tennessee. It will be 253 ft. high from foundation to roadway, 210 ft. thick at the base and 1800 ft. long at the crest. The waters impounded by Norris Dam will form an artificial lake of 3,600,000 acre-feet covering some 80 sq. miles with a shore line of more than 800 miles. The cost of the dam is estimated at about $34,000,000. Two 60,000-horsepower generating units will be installed in the power house.

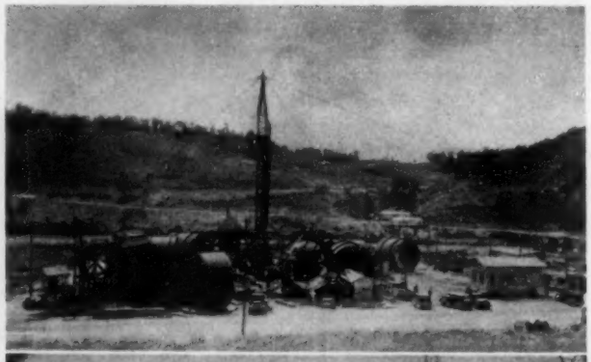


Fig. 1—Fabricating Site Where Steel Plate Was Welded into 20-Ft. Diameter × 20-Ft. Sections in Construction of the Penstocks for the Norris Dam, TVA Project

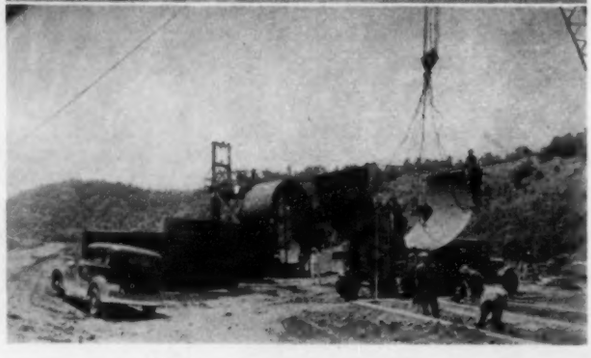


Fig. 2—A Semi-Cylindrical Section of Steel Plate, Two of Which Welded Together Form One of a Series of Steel Rings Used in Norris Dam Penstock Construction

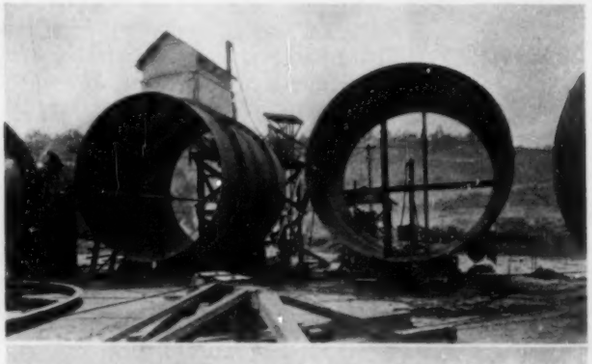


Fig. 3—Joining Two 10-Ft. Sections in Constructing 20-Ft. Diameter Penstocks. At Extreme Left the Arc-Welding Operator Is Welding on a Steel Stiffening Ring

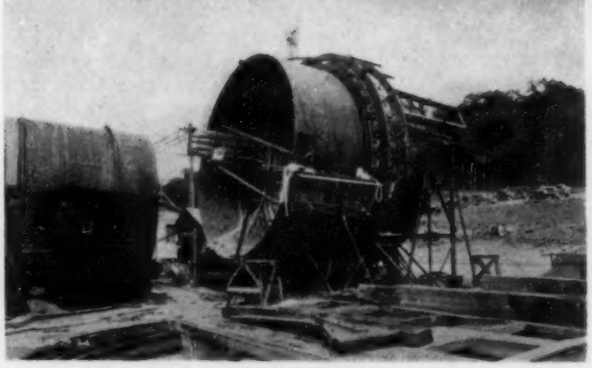


Fig. 4—Stress-Relieving the Welding by Electricity. Joints after Being Heated to Proper Temperature Were Allowed to Cool Uniformly with Heating Elements and Insulating Blankets in Place

Each of the two penstocks was built of plates formed in semi-cylindrical sections at the Birmingham plant of the Chicago Bridge and Iron Works and shipped to the site of the dam (see Figs. 1 and 2).

At a field-fabricating plant four plates were welded together to form a section 20 ft. in diameter by 20 ft. long. The heaviest of these sections weighed approximately forty tons. The automatic welding at the field plant was carried out as follows: first, two plates forming a cylindrical section 20 ft. in diameter 10 ft. long were tack-welded together in a special fitting-up form. The seams joining these plates were then welded by the automatic welder. Two of these 10-ft. sections were then tack-welded together and placed on power driven rolls (see Fig. 3) which turned the pipes for making the automatic circumferential weld. All automatic welds were of the double "U" type.

As a means of stiffening the penstock a steel ring $1^7/_{16}$ x 8 in. was welded around the outside of each 10-ft. section.

After welding, all welded seams were X-rayed and all defects disclosed by the

† Vice-President, The Lincoln Electric Company

Fig. 5—A Section Entirely Fabricated by Arc Welding, Being Swung Into Place by Overhead Cableways in Construction of Two 20-Ft. Diameter Penstocks at Norris Dam

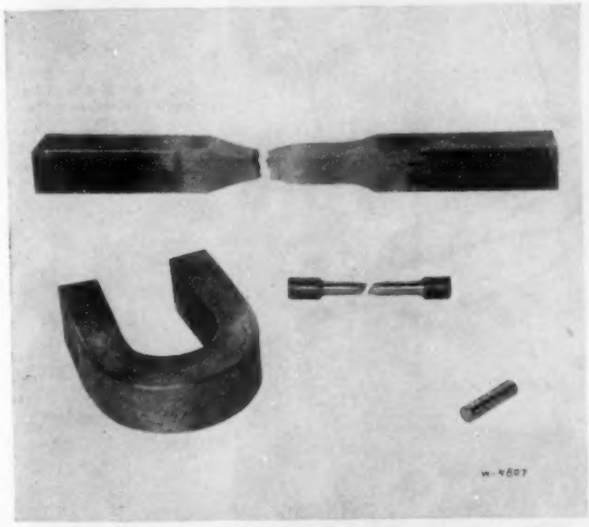


Fig. 6—Test Samples of Welded Joints of Penstocks Show Physical Properties Satisfactory to Requirements of A. S. M. E. Boiler Code for Class 1 Welded Construction. (Top) Transverse Test Specimen. (Bottom Left) Free-Bend Test. (Lower Middle) Tensile Test All-Weld-Metal Specimen. (Lower Right) Specific Gravity Specimen

X-ray photographs were repaired. The welded joints were then stress-relieved electrically (see Fig. 4). After being heated to proper temperature the welds were allowed to cool uniformly with the heating elements and insulating blankets in place. During heating and cooling, protection from the weather was provided by a temporary housing erected over the pipe.

Tests were made of the welded joints by cutting samples from test plates welded under identical conditions. The specifications for the work required an all-weld metal sample to show a tensile strength of 55,000 lb. per sq. in., ductility of 20% elongation in 2 in. and specific gravity of 7.80. Also, a free-bend test was required to show 30% elongation in outside fibers without any indication of fracture or tear.

After approval by the inspector, each 20-ft. section was hauled from the fabricating site on a heavy-duty trailer and swung into position on the dam by overhead cableways (see Fig. 5). When properly placed, the sections were welded together by the manual shielded-arc process of welding. When all welding was completed the insides of the penstocks were sand-blasted and given a coat of paint.

The two penstocks were built under the direction of O. A. Bailey, Chief Engineer of the Chicago Bridge and Iron Works, to which company should go considerable credit for completing the job on schedule.

Barton M. Jones, Construction Engineer on the Norris Dam, in commenting on the welding of this project, says: "I was very much pleased with the speed at which the welding work was done, since it had to meet our very stringent requirements in all details."

Fig. 7—New Arc-Welded Bubble Tower Built by the Chicago Bridge and Iron Works Is the First of Its Kind to Be Constructed under the New Vacuum Code

Fig. 8—An Arc Welder at Work Constructing a 55-Ft. Bubble Tower for Production of Finished Asphalt at Maurer, New Jersey. This Tower Will "Grow" 2¾ In. Taller When Operated at 650 Deg. Temperature

Arc-Welded Bubble Tower Grows 2¾ In. Taller in Service

A bubble tower, which grows 2¾ in. taller in service and which is the first of its type to be built under the new Vacuum Code, is under construction at Maurer,

New Jersey, for the Barber Asphalt Company. This equipment is part of a vacuum distillation unit designed and installed by The Lummus Company for production of asphalt. The tower is being erected by the Chicago Bridge and Iron Works. It is of arc-welded construction throughout.

The tower is 55 ft. high, 15 ft. diam. and will operate at 650° F. under vacuum. At this high temperature the structure is $2^{3}/_{4}$ in. taller than when cold. It is being entirely fabricated in the field with the exception of the bonnet.

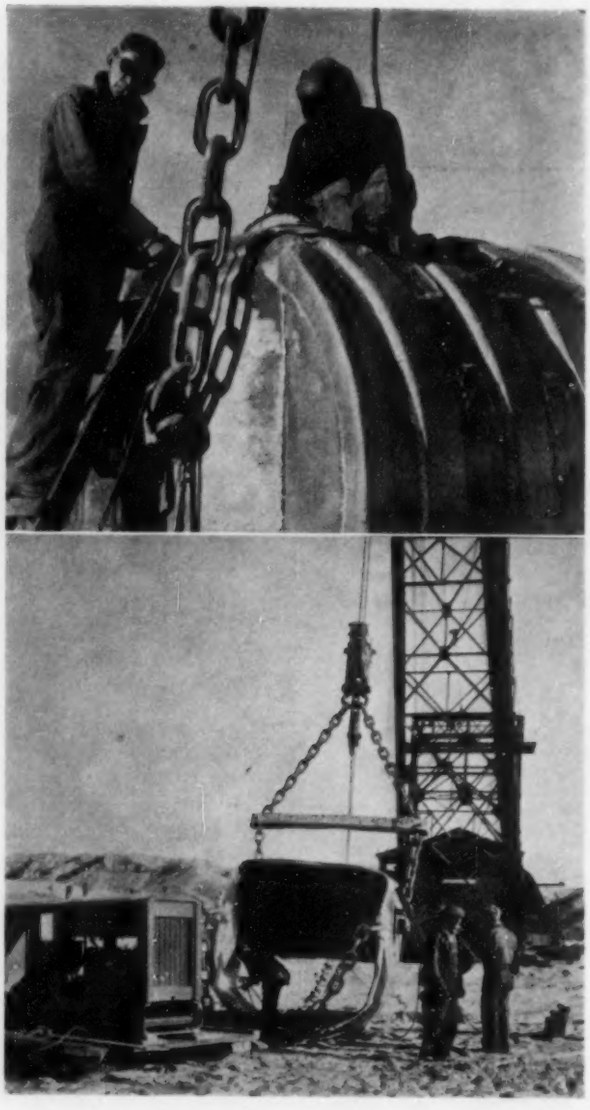
The shell is built of steel plates ranging from $^{7}/_{8}$ in. thick at the bottom to $^{3}/_{4}$ in. thick at the top. All joints in the shell are butt joints. In the horizontal joints the plates are vee'd to 45° with $^{1}/_{8}$-in. point. In the vertical joints the plates are vee'd to 60°. All joints in the shell are welded with $^{5}/_{32}$-in. electrode.

The decks, or bubble trays, inside the shell are built of $^{1}/_{4}$-in. plate. Each tray contains 36 risers and is supported on angles welded to the inside of the shell. The trays and supporting angles are welded with $^{7}/_{32}$-in. electrodes.

Arc welding is used to particular advantage in construction of this bubble tower. In addition to high ductility, the shielded-arc weld metal shows a tensile strength of 65,000 to 75,000 lb. per sq. in. Resistance to corrosion, so important in a structure of this type, is assured by the welded joints since the shield arc provides weld metal of greater corrosion resistance than cold-rolled steel.

Drag-Line Bucket

This giant drag-line bucket has the job of chewing away some 40,000,000 cu. yd. of earth in the construction of the All-American Canal, 75-mile federal irrigation project, in Southern California. No wonder that in between its 12 cu. yd. bites it must pause once in awhile for dental attention. The "filling" is applied by the electric arc-welding process.



Figs. 9 & 10—Drag-Line Bucket Undergoing Repairs

Tantalum Sheets 0.005 In. Thick Now Welded by the Electric Arc

Tantalum sheets worth $50 a lb. and so thin that it takes 200 of them to make an inch are now being arc welded regularly in the fabrication of chemical equipment.

The metal tantalum possesses characteristics which make it especially valuable in the manufacture of all types of laboratory accessories. It is not tarnished by air nor attacked by acids, except hydrochloric. In tensile strength it is $2^{1}/_{2}$ times stronger than platinum. It combines softness with workability and has great resistance to wet corrosion.

Tantalum is a rare metallic element found in association with niobium and little used commercially until recent years. Most of the supply comes from Australia, although it is found in the United States in small quantities in North Carolina, Colorado and in the Black Hills of the Dakotas. Sweden, Norway, Greenland, Madagascar and Rhodesia are other localities where it is known to exist.

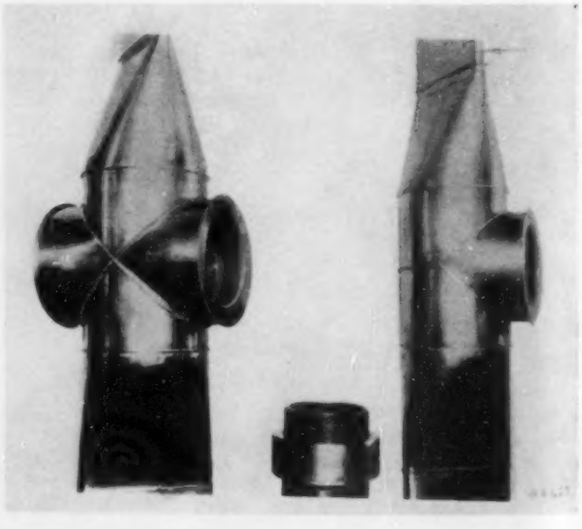


Fig. 11—Tantalum Sheets 0.005 to 0.025 In. Thickness Are Being Fabricated Regularly into Chemical Equipment with Arc Welding by Fansteel Products Company, Inc., North Chicago, Illinois

Fansteel Products, Inc., Chicago, Illinois, are one of the largest suppliers of tantalum. It is this company which developed and perfected a method for weld-

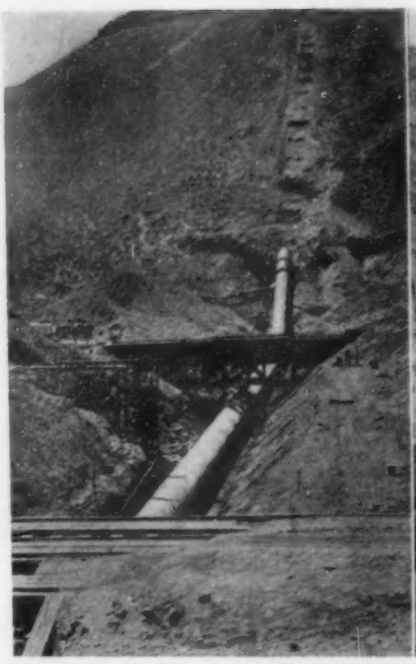


Fig. 12—The Owyhee Siphon after the Lower 700-Ft. Section across the Owyhee Canyon Had Been Completed. The Trestle Was Used for Diverting the Water from the Owyhee River While the Pipe Was Being Laid

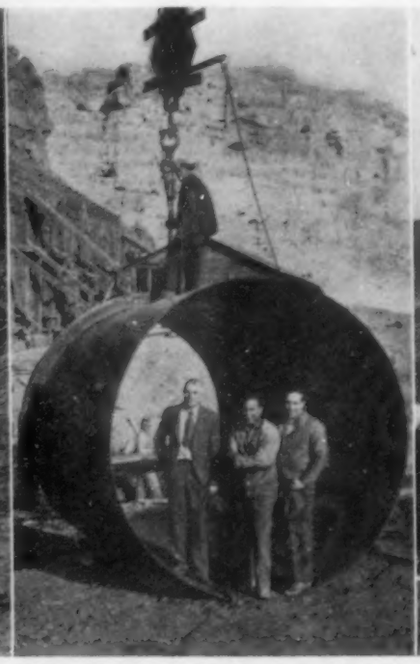


Fig. 13—The Pipe Used is 9 Ft. in Diameter, Varying in Thickness between 3/8 In. and 15/16 In.

Fig. 14—A Slope of 42 Deg on a Hillside Which Carries a Part of the 1630-Ft. Owyhee Siphon

ing this rare metal, thereby increasing its field of usefulness.

Exacting requirements covering the articles fabricated from tantalum have made it necessary to develop a special technique for welding it. Some of the most important factors which must be considered in working with this metal are as follows:

1. Tantalum is a very valuable metal, costing approximately $50 per lb.—more than $3 an oz.
2. Inasmuch as most of the articles are custom made, the labor cost is rather high. Spoilage must therefore be reduced to a minimum.
3. Finished welds must be strong, ductile and both gas and liquid tight under pressure and vacuum.
4. Tantalum cannot be deposited from an electrode without so embrittling the welds as to make them unusable.
5. Tantalum cannot be heated in air much above 650° F. without becoming hard and brittle.
6. The melting point of tantalum is above 5100° F.

The method finally adopted consists of first forming a straight angle flange at all edges of the sheets to be arc welded. These flanges are then fitted together and tack-welded in a few places to avoid shifting the assembly.

The job is then immersed in a tank filled with carbon tetrachloride so that the edge to be welded is approximately 1/4 in. below the surface of the liquid.

Immersion in carbon tetrachloride requires higher voltage across the arc than would be needed to weld in air and, at the same time, the thinness of the stock being welded and the necessity for strict localization of the heat demand low welding current. Hard carbon electrodes 1/8 in. in size, held in small light electrode holders, are used. The welding current must be of normal polarity.

Stability of the arc and ease of striking it as well as freedom from blowing are absolutely essential for producing good welds. An open-circuit voltage of 50 which falls to about 25 across the arc usually produces satisfactory welds.

Current depends on the thickness of metal, 0.005-in. stock requiring only 15 amp. and 0.025-in. 60 amp.

Welding is accomplished by melting the edges of the flanges so that the metal runs together. This must be accomplished quickly since holding the arc in one spot or striking it more than once in one place is likely to result in brittle welds.

While it is apparent that special technique and considerable care are essential in arc-welding tantalum, very satisfactory work is being done regularly on both large and small jobs.

Arc Welding Used in Construction of Two Huge Siphons

Two huge siphons, one 10 ft. 6 in., the other 9 ft. in diam., are being constructed by arc welding on the Owyhee river in eastern Oregon for the Bureau of Reclamation. The 9-ft. pipe is being welded into one solid tube 1630 ft. long. The 10 ft. 6 in. section is 900 ft. in length. Both are being constructed of pipe and materials furnished by the federal government and are a part of the North Canal in the Mitchell Butte diversion of the Owyhee project.

The first pipe to be installed in the Owyhee siphon was placed in the bottom of the Owyhee Canyon June 1, 1934. This section of the project is 700 ft. in length and constructed of 9 ft. diameter pipe, fabricated from 3/16-in. steel plate. This pipe is placed in a trench 29 ft. deep and will be completely encased in concrete. Figure 12 shows this section of the line after it had been installed.

After the lower section was welded in place, heavy test heads were welded on each end and the line tested to 200 lb. for a period of 12 hrs. Following this test, the same pressure as that effective when the siphon is placed in use was held in the line during the time the concrete was being poured and for ten days afterward, making a total test period of approximately 30 days. There were no leaks whatever in the field welding of this section.

The field joints on the encased portion of the Owyhee siphon were butt vee type with no backing-up strap, while the joints on the exposed section were butt vees with an outside butt strap 3/8 in. thick.

High Temperatures Cause Difficulty

High mid-day temperatures (125° in the shade), caused some difficulty in fitting the joints. In the case of the flat river section, after the string became more than 200 ft. in length, it was found that the top of the pipe had a tendency to become longer than the bottom. A method was devised whereby the tops of the sections were secured by tack-welding and the bottoms by pull jacks, leaving a gap at the bottom sometimes as much as 1/4 in. greater than the top gap. The following morning, with the temperature equalized, no trouble was experienced in bringing the pipe flush and in tack-welding.

The welding was accompanied by a

thorough peening with pneumatic tools. Skilled pipe welders were qualified by test. Two-thirds of the joints required staging inside and out due to the steep grades. A total of 13 passes and 41 hrs. was required for each $^{13}/_{16}$-in. butt vee joint.

The trestle shown in Fig. 12 was used for diverting the Owyhee river while the pipe was being laid. After the job is finished, the river will be above the siphon.

At the present time the pipe on the two hillsides of the Owyhee siphon is being installed and is practically completed. The plate used on the hillsides ranges from $^{13}/_{16}$ in. to $^{5}/_{8}$ in. Figure 13 gives an idea of the size of the pipe. Just how steep the hillsides are is shown in Fig. 14 where the grade is 88% at the steepest point.

Pipe 10$^{1}/_{2}$ Ft. in Diameter

The pipe-line shown in Fig. 16 is the Sniveley siphon, located about three miles from the Owyhee siphon, and a part of the same canal which goes through the Owyhee project. The pipe used in this part of the job is 10 ft. 6 in. in diameter, ranging in thickness from $^{1}/_{2}$ in. to $^{3}/_{8}$ in.

The Sniveley siphon was started just after the lower crossing of the Owyhee siphon had been finished. This siphon is 900 ft. in length.

Pipe was delivered in 20-ft. lengths and placed by a crane where conditions permitted. On the steep slopes the pipe was slid over the piers on rails.

The pipe is entirely supported on rollers and anchors. The welded joints used in joining the pipe were similar to those used on the exposed portion of the Owyhee section, that is, butt vee with a $^{3}/_{8}$-in. butt strap on the outside. Each joint required nine passes and 29 hrs. welding time.

A test of the Sniveley siphon revealed no leaks whatever in the field welding. Figure 15 shows part of the Sniveley siphon, including expansion joints and anchors.

A crew of approximately 25 men and four arc-welding machines handled the placing of the pipe and the field welding on these two projects. The Olson Manufacturing Company of Boise, Idaho, placed and welded the pipe under the direction of Mr. Hanford Haynes, Superintendent. Two sizes of electrodes—$^{5}/_{32}$ and $^{3}/_{16}$ in.—were specified by the Bureau of Reclamation and supplied by our company. The pipe was furnished by the Chicago Bridge and Iron Works.

Both of these siphons would have been completed in much shorter time had it not been for the fact that the government decided to stress-relieve the field welds. This was done by using an oil-fired portable ring furnace which heated the joint to 1100°, at which temperature it "soaked" for about an hour and then was allowed to cool gradually. Temperatures were recorded by thermocouples at eight points on the ring.

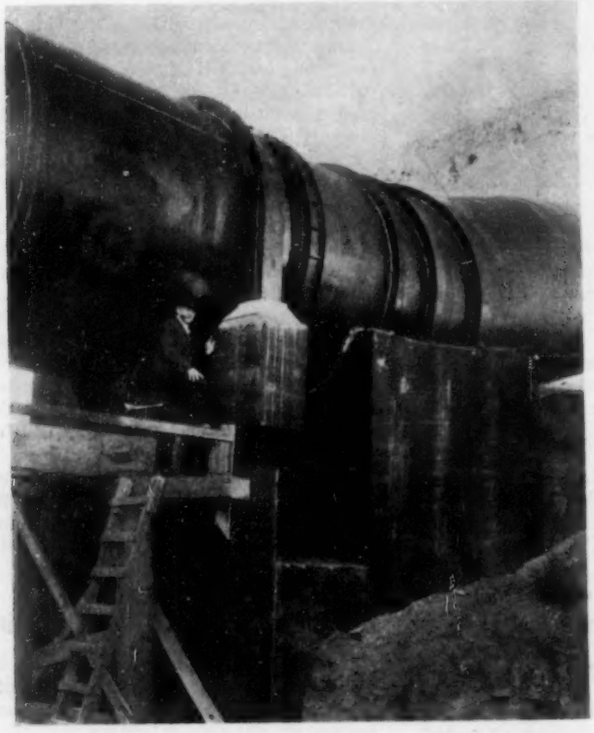
Electric Arc Constructs 84-In. Rocky Mountain Pipe-Line

Not a single leak was found in testing the 1$^{1}/_{2}$ miles of arc-welded 84-in. water pipe-line completed recently high up in the Rocky Mountains for the Santa Maria Reservoir Company, located 30 miles west of Creede, Colorado.

The pipe used in construction of the Santa Maria line was fabricated entirely by arc welding. Shop seams were welded automatically, pipe elbows manually (see Fig. 16).

Three thicknesses of pipe were used. About 10 per cent was $^{1}/_{4}$ in., 55 per cent $^{5}/_{16}$ in. and the balance $^{3}/_{8}$ in. The pipe was fabricated in 35-ft. lengths and the

Fig. 15—A Close-Up View of the Expansion Joints and Anchors of the Sniveley Siphon



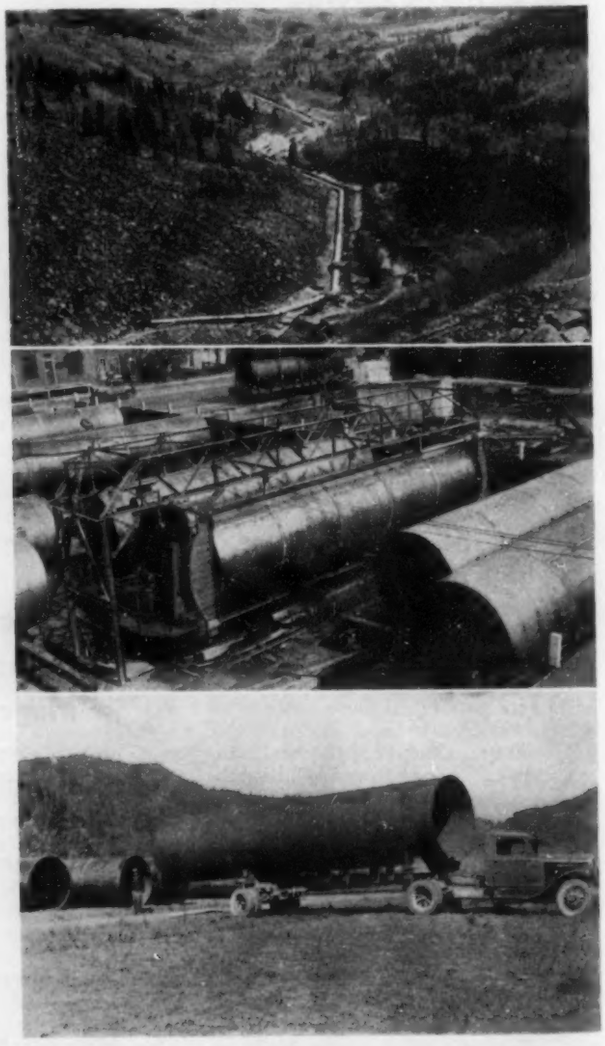


Fig. 16—Birdseye View of Santa Maria Pipe-Line Constructed Entirely by Arc Welding at an Altitude of 10,000 Ft. in the Rocky Mountains (Upper Right)

Fig. 17—Using a Special Testing Machine to Test Pipe at a Pressure of 186 Lb per Sq In. Following Fabrication by Arc Welding (Center)

Fig. 18—A 35-Ft., 84-In. Diameter Pipe Weighing Six Tons Transported 30 Miles over Mountain Roads in Construction of Santa Maria Pipe-Line (Lower Right)

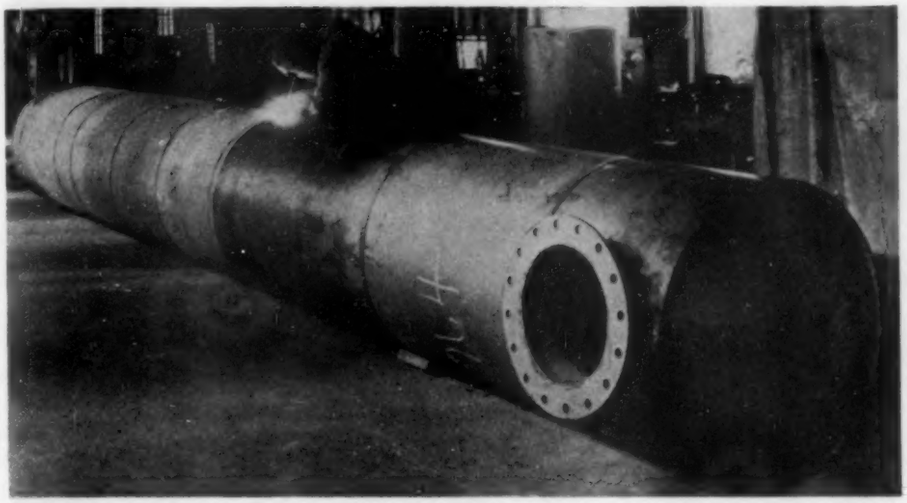


Fig. 19—A Maxim Silencer under Construction by Arc Welding in the Hartford, Connecticut, Plant of the Maxim Silencer Company

entire contract involved about 1300 tons of steel.

Every foot of the pipe was tested after fabrication by a special testing machine (see Fig. 17). The $^{3}/_{8}$-in. pipe was tested at 186 lb. pressure per sq. in., the $^{5}/_{16}$ in. at 165 lb. per sq. in.

Getting the pipe the 350 miles from Denver to the site of the pipe-line required moving it 320 miles by train and then 30 more miles over mountain roads. There were approximately 135 car-loads of pipe, each load consisting of two lengths of pipe, weighing about 6 tons each. Only one length of pipe could be carried per trip by trucks (see Fig. 18).

A set of test specimens was taken for each three lengths of pipe. The tensile test specimens were nicked so that they would be forced to break in the weld. Most of these specimens showed a tensile strength of 80,000 lb. per sq. in., compared with a tensile strength of 55,000 to 65,000 lb. per sq. in. in the parent metal of the pipe itself.

About 10 per cent of the pipe-line traversed disintegrated rocks which required mounting the pipe on rollers installed on concrete piers. The pipe on this section of line was given added supporting strength by welding stiffener rings outside the pipe. These rings were welded in place with $^{1}/_{4}$-in. electrodes.

The official field test consisted of welding a head in the outlet end of the line and filling the line full of water, allowing it to remain under a pressure of 100 lb. per sq. in. for a period of 24 hours. Not a single leak was discovered in the entire $8^{1}/_{2}$ miles of arc-welded seams and joints.

G. H. Garrett, chief engineer of the Santa Maria project, referring to the complete absence of leaks, said:

"We have read of a great many other pipe-lines being tested in various parts of the country, and so far this is the first pipe-line we have heard of that has been entirely water tight in the final test. It was expected that some of the field seams might leak under the severe test, but there was absolutely no leakage."

All welding, both in the shop and field, was done by the Thompson Manufacturing Company of Denver, Colorado. The pipe was fabricated entirely by arc welding, using the "Electronic Tornado" process of automatic welding. The field welding was done with shielded arc electrodes.

Electric Arc Silently Fabricates Silencing Equipment

When this country's largest all-welded commercial vessel, the motor tanker *Poughkeepsie Socony* set sail on her maiden voyage between New York and Great Lakes ports, noises from her twin 375-hp. Diesel engines were muffled by silencers silently fabricated by arc welding at the plant of the Maxim Silencer Company, Hartford, Connecticut.

The silencers which the Maxim Silencer Company builds for various Diesel engine manufacturers, boat builders and makers of other equipment which produces explosive noises, vary in size according to the equipment with which they are to be used. The size range extends from 1 ft. to 30 ft. in length, 6 to 60 in. in diameter and 25 to 10,000 lb. in weight. The steel used in construction varies between 20 gage and $^{1}/_{4}$ in. thickness.

The pressure to which a silencer is subjected normally is only a slight back pressure developed in muffling the exhaust of the engine. In ordinary service, this pressure does not subject the equipment to any great stresses. However, unburned gases occasionally escape through the exhaust system and find their way into the silencer where they explode. These gases, exploding in the silencer, subject the equipment to extra pressures.

In order to provide the required strength in this equipment, the makers employ arc-welded construction exclusively. They have found that the shielded-arc process of welding provides tensile strengths of 65,000 to 85,000 lb. per sq. in., ductility of 20 to 30% elongation in 2 in., with fatigue and impact resistance equal to mild rolled steel. Added to these results, the company reports considerable saving in time and cost of construction over former methods of fabrication.

In welding the silencers, most of the welded joints are of butt and lap type, similar to that used in tank work. There is an exception, however, in the case of the ends of smaller cylinders. In welding these parts, edge welds are used.

Most of the welding is done in the down position, since the cylindrical shape of the silencers permits rolling them during welding. Two sizes of electrodes, $^{5}/_{32}$ in. and $^{3}/_{16}$ in., supplied by us are used. The accompanying illustration shows a welding operator at work on one of the silencers. (Fig. 19.)

This plant uses four arc-welding machines. In addition, they recently placed an order for a new 75-amp. welder, especially for use on thin-gage materials. The Company intends to use the new welder on all materials of 16 and lighter gages.

Ocean Pier, 2327 Feet Long Constructed by Arc Welding

Arc-welding operators, hanging in "bosuns' chairs," most of the time uncomfortably close to 20-ft. seas, made over five miles of welded joints in erecting the steel framework of a new 2327-ft. ocean pier recently completed on the rugged, unprotected California sea coast at Davenport.

This $^{1}/_{2}$ mile long pier (see Fig. 20), which required over a year to build, was constructed for the Santa Cruz Portland Cement Company by Merritt-Chapman & Scott, San Francisco, California, as contractors, under the direction of R. C. Helen, Superintendent, as part of its plan to transport bulk cement from its plant at Davenport, California, where there is no harbor, to various points along the west coast. The pier carries two 12-in. pipe-lines for cement, one 6-in. oil-line and one 3-in. water-line.

In order to provide a structure that would withstand the constant battering of the waves, not a bolt nor a rivet was used. All connections were made by arc welding.

To meet engineering as well as shipping requirements in building the pier, it was

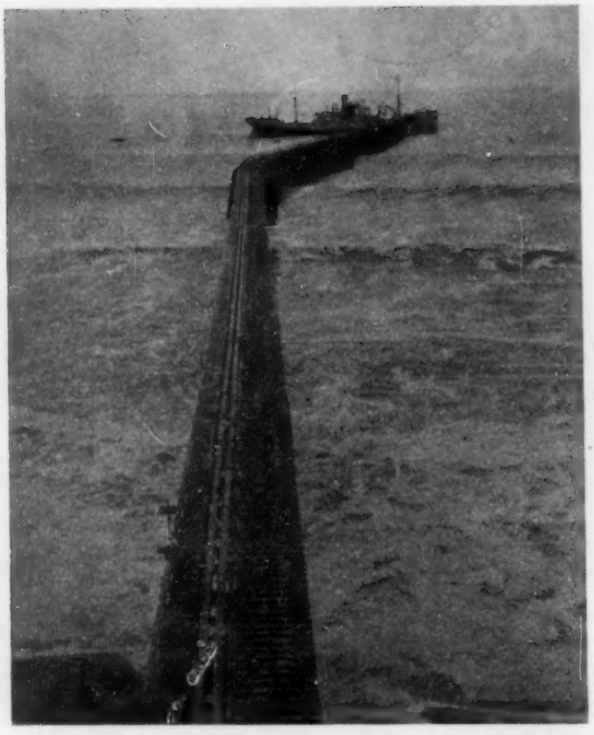


Fig. 20—The 2327-Ft Arc-Welded Pier Constructed on California Sea Coast for Loading Bulk Cement from Shore Silos to Ship through Pipe-Lines

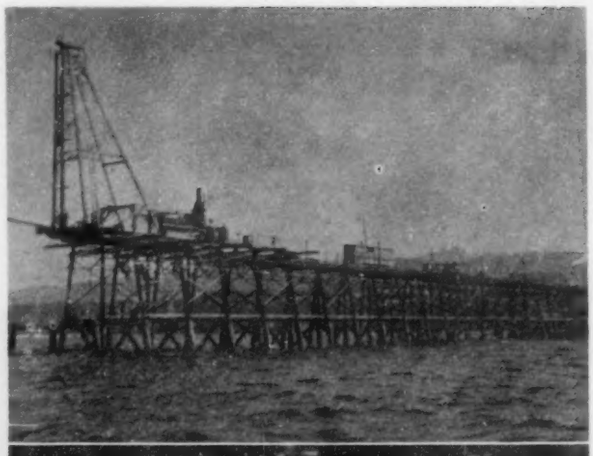


Fig. 21—Picking Up a Steel H-Column Pile Used in Construction of California Shore-to-Ship Arc-Welded Loading Pier for Bulk Cement (upper right)

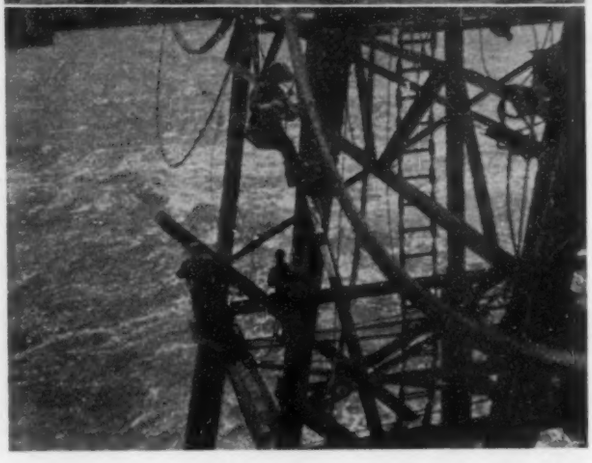


Fig. 22—Arc-Welding Operator in a "Bosuns' Chair" Welding Trusses of All-Welded Loading Pier, Which Required 22,150 Lb. of Electrode (lower right)

necessary to make a survey of the ocean bottom for the entire length of the proposed structure. This survey, made in September 1933, required taking soundings, shale elevations and sand depth. The bottom was found to be shale the full length of the project, with sand depths varying between 6 in. and 6 ft. A careful check was made to be sure the extending pier would be headed directly into the seas.

H-Column Piles Used

From the results of the survey it was decided to use H-column piles (see Fig. 21), and to drive them to refusal with as much penetration as possible. The adhesive and bond value of the shale was determined by test.

A combination steel cylinder and H-beam pile trestle, well braced and carrying a timber deck, was designed. The procedure adopted for construction consisted of completing each bent and span of the pier before starting the next. All connections were arc welded, there being over five miles (26,790 lin. ft.) of welding in the entire structure. More than 22,000 lb. of electrode were used.

The first 840 ft. of pier consists of 56 bents on 15-ft. centers, each bent having three 33-lb. H-column piles. The two outside piles are battered 12 on 1. Each bent is X-braced with every other bent sway-braced by 4 x 4 x $^{3}/_{8}$-in. angles. The three piles are tied together with a sash brace. A longitudinal brace of 4 x 4 x $^{3}/_{8}$-in. angles carries through on each outside pile of the bent. The piles are tied together longitudinally by a truss 4 ft. deep. All braces are electrically welded and the bents are capped with 12 x 12-in. x 16-ft. timbers.

Completion of the 840 ft. from the abutment brought the pier to the breaker line where the water had a depth of 14 ft. at mean lower low tide. Since the breaker line is the point of greatest wave force, heavier construction was used through the breaker line and for the remaining 80 bents of pier which were spaced on 18-ft. centers.

Procedure Followed in Construction

The procedure followed in constructing the 136 bents of pier required a temporary guide frame to hold the cylinder piles in place and, at the same time, provide a working platform while driving the piles. This frame was held at an elevation of 1 ft. below the cylinder cut-offs by cables from the last completed bent. The frame was left in place until the entire bent was finished, after which it was picked up and moved ahead for the next bent. With the frame in position, the three cylinder piles were driven and cut off to their proper elevation . The sand was removed from the piles by compressed air and the three standard 10-in. 49-lb. H-column piles driven with a drop-hammer to obtain maximum penetration. So hard was the driving that the heads of the piles were battered by the blows and had to be cut off several times.

Following the driving of the piles, the lower sash brace was placed and spot-welded. The piles were then cut to grade and a temporary 12 x 12-in. x 36-ft. wood cap placed on the piles for supporting the pile driver and to provide a working platform. Two 12-in. channel-iron caps were hung and the bent was ready for X-bracing. The two brace piles were driven, brought into position and welded. The longitudinal struts were placed, the bent sway-braced and the trusses hung. The X-braces under the deck were placed and a carpenter crew laid the wood deck.

After completing the steel work on a bent, the cylinders were watered and the concrete poured. Placing the concrete was done through pipes.

Welding Done under Difficulties

The welding was carried on in conjunction with the pile driving and steel erection (see Fig. 22). All braces were tacked in place and welded. As the welding on each bent was completed, the temporary framework was moved ahead and welding started on the next bent. It was absolutely necessary to complete the welding of each bent before moving ahead as any work not tied together would be knocked down by the heavy seas which came without warning. About 24 hrs. were required for welding each bent of the pier.

The welding was carried on almost entirely from "Bosuns' chairs" and work was seriously hampered by rolling seas. The welding of the bottom braces was done under particularly trying and hazardous

conditions. It was often necessary to place one man to watch the seas and warn the welders and workmen to start climbing when a large wave came along. A diver followed the welders and placed the underwater clamps which hold the brace piles to the center pile of each bent.

All materials used in construction had to be handled over a 50-ft. bluff with a 100-ft. boom stiff-leg derrick and carried out on the pier on cars pushed by a small locomotive. Concrete materials were handled in skips loaded on cars and pushed out behind the concrete mixer, also mounted on a car behind the pile driver.

Tunnel from Cement Silos to Pier

In order to transport the cement from the storage silos at the plant to the ship, a 6 x 7-ft. tunnel 360 ft. long was driven from the silos to shore end of the pier. Two 12-in. pipe-lines carry the cement which is pumped from the silos through the tunnel and along the pier to the ship.

A 36-ft. square pier head was constructed at the sea end of the pier. This was supported by four 7-ft. diameter cylinders anchored into the shale by six H-piles driven in each and filled with concrete. The cylinders were placed 36 ft. apart to form the square and were tied together with structural steel, all welded.

Underwater Cutting with Oxyelectric Torch

Placing the cylinders for the pierhead required driving falsework piling and 34 steel H-beams which were later cut off at the ground line by a diver using an oxyelectric underwater cutting torch, with current generated by a 300-amp. arc-welding machine.

When a ship is taking on a cargo at the pierhead, it is necessary that it lay free of the end of the pier in order to prevent the ship being driven against the pier by the ever-present ground swells rolling in from the sea. The ship is held off the pier by eight moorings, consisting of old-fashioned 16,000-lb. stock anchors, with 60 fathoms of chains, supported by a buoy. To give the anchors a hold on the bottom, holes were dynamited in the shale for the flukes. Of the eight moorings, four are provided for the bow and four for the stern of the vessel. These moorings are placed so that the ship's bow is held head on into the seas.

A small derrick at the end of the pier handles the two 12-in. hose from the ends of the cement pipe-lines to the ship. Each 12-in. line carries 1000 barrels of cement an hour.

The design and construction of the pier were carried out by the West Coast division of Merritt-Chapman & Scott Corp., with R. C. Helen in direct charge of operations for the contractor. Parson, Clapp, Brinkerhoff and Douglas of New York acted as consultants in working out the design.

Tests Show No Leaks in 36-Foot Arc-Welded Sphere

By T. W. COOK†

ELECTRIC arc welding was used in the construction of a 36-ft. steel sphere, designed and erected by the Chicago Bridge and Iron Works at the General Electric Company's Plant on East 152nd Street, Cleveland, Ohio, and no leaks whatever showed up in subsequent tests.

This sphere, known by its trade name as a "Hortonsphere," is used to contain natural gas, and its purpose is to maintain pressure and B. t. u. content constant at all times. Thirty-six feet in diameter, the sphere has a volume of 24,400 cu. ft., but at its normal working pressure of 29 lb. per sq. in., its storage capacity is an additional 50,000 cu. ft.

In construction, the steel was cut to size and formed in the shop, hauled to the job, hoisted into position and welded in place. Two 400 amp., single operator welding generators were used to produce the 800 lin. ft. of welding required in the erection of the sphere, whose steel walls are approximately $^{5}/_{16}$ of an inch thick.

Following completion, the sphere was tested in two different ways for possible leaks. In the first, the conventional soapy water test was used, and in the second test, a pressure of 38 lb. per sq. in. was put on the sphere and held for 48 hrs. A recording pressure gage on the sphere recorded pressure throughout this test, and a record of temperatures was kept in order that pressure changes due to changes in temperature might be taken into account. As stated above, neither test showed the slightest trace of a leak.

† News Bureau, General Electric Company.

Welding Requirements of A. S. M. E. Code*

By W. D. HALSEY†

THE chart on the next page was compiled by the Hartford Steam Boiler Inspection and Insurance Company, of Hartford, Connecticut, to show the welding requirements of the A. S. M. E. Boiler Code, which Code is subdivided into a number of sections as shown at the top of the chart. The restrictions on, and requirements for, welding are different in each of the various sections and it is the purpose of the chart to make these differences clear.

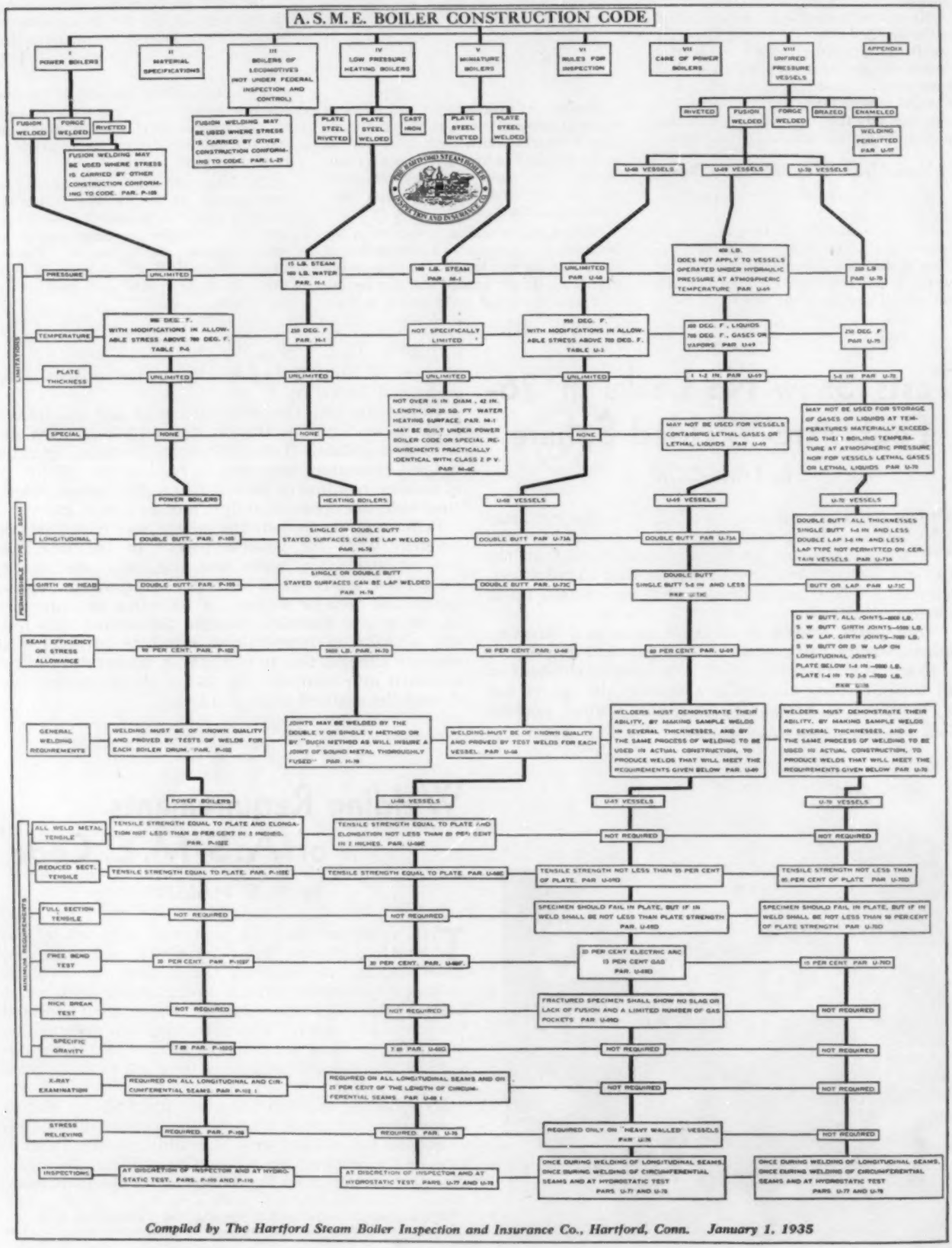
By following through the chart from top to bottom along the heavy guide lines, the limitations on, and requirement for, welding may be readily found. In addition to the information relating to welding, the chart also gives certain other limitations such as pressure, tem-

* Presented at December 11, 1934 Meeting, New York Section, A. W. S.
† Asst. Chief Eng., Boiler Division, The Hartford Steam Boiler Inspection and Insurance Company.

perature, plate thickness, that are permitted; and information is given as to the permissible type of seam that may be used, with the seam efficiency or stress allowance in each case.

The chart brings out an outstanding difference between the requirements for power boilers and U-68 vessels (formerly known as Class 1 vessels) and the requirements for U-69 and U-70 vessels (formerly known as Class 2 and Class 3 vessels, respectively).

In the case of fusion-welded power boiler drums and



fusion-welded U-68 vessels, the soundness of the seams must be determined by X-ray examination and the physical properties of the welded joint must be determined by test of the weld for each vessel. On the other hand, in the case of U-69 and U-70 vessels, no X-ray examination or physical tests of the welding for each vessel are required. In lieu of such examination and test, it is required by the Code that the manufacturer decide upon a definite technique of welding and that the individual operators of the welding equipment make test welds in various thicknesses of plate under such technique of welding. These welds are subjected to various tests as shown in the chart and, if the results are satisfactory, the operators who made them are permitted to weld on U-69 or U-70 vessels, as the case may be. Thus, it is assumed in the case of such vessels that if a definite technique of welding has been adopted and proved by test to give satisfactory results and, if the individual operators of the welding equipment have shown themselves capable of making welds under that technique that will meet Code requirements, the welding on any particular vessel under that technique and by those operators may be considered as satisfactory for the purpose intended.

There are, of course, many details appearing in the Code that it is impossible to bring out in a chart of this nature. However, reference has been given to the Code paragraph from which any specific requirement shown on the chart has been obtained, and reference should be made to such paragraph for complete information.

Stress-Relieving Welded Pipe Joints by 60-Cycle Induction Heating

By A. P. FRUGELL† and D. H. COREY††

IT IS often desirable to stress-relieve fusion welds in a pressure piping system. To relieve, properly, welding stresses in a circumferential pipe weld, the weld and a length of pipe on each side of it equal to about six times the wall thickness should be heated to a comparatively uniform temperature of 1100 to 1300° F. which should be maintained for a period of time equal to one hour for each inch of pipe wall thickness.

A convenient and satisfactory method of accomplishing this stress-relief by an application of electric induction heating in the pipe has been developed by The Detroit Edison Company. In the course of this development, a large number of experiments was made on pipe from 4 in. to 16 in. in diameter. In addition, about sixty welds in pipes ranging in size from 2½ to 8 in. were stress-relieved by this method under conditions duplicating those in central-station power plants. A brief description of the method and equipment used will be given.

† Engineering Division, The Detroit Edison Company.
†† Welding Engineer, D. & S. Bureau, The Detroit Edison Company.

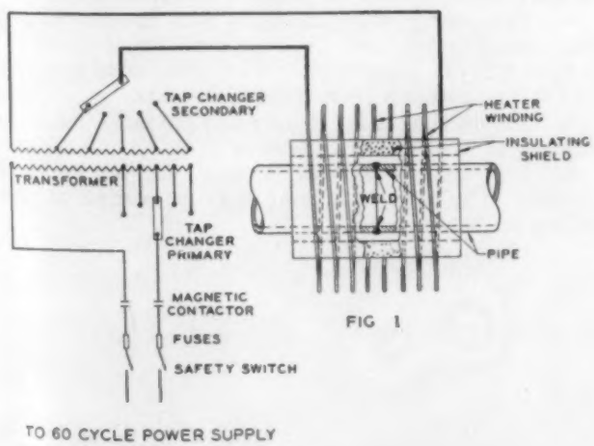


FIG 1

The general scheme is quite simple, consisting merely of wrapping several turns of a conductor around the pipe directly over the weld and passing 60-cycle current through this winding. A moderate amount of heat insulation is used between the heater winding and the pipe to protect the winding from the heat in the pipe. The mechanics of designing a winding which could be placed around the welded joint conveniently after the pipe was installed, of obtaining heat insulation of proper mechanical properties which would stand the high temperature, of determining the proper electrical characteristics of the heater winding and of obtaining a winding which would provide sufficient ampere turns without exceeding permissible temperature or requiring too much space, was more involved and required considerable experimentation. Figure 1 shows the schematic arrangement of equipment as evolved, with the major electrical wiring connections.

For the original experiments, conventional heat insulating pipe covering was placed around the pipe and, over this, copper tubing was wrapped until the required number of turns was obtained. The tubing was wrapped with insulating tape to provide turn-to-turn insulation and water passed through the tube to provide the necessary cooling. Though satisfactory results were obtained, the installation of the equipment was rather awkward and would be even more so during actual service. Hence, for actual use in the field, an insulating shield of heat-resisting material held away from the pipe by steel rings and a self-cooled heater winding cut from plate copper or aluminum were constructed. Both shield and winding were hinged so that they could be opened to slip over the pipe and then closed and bolted into place ready

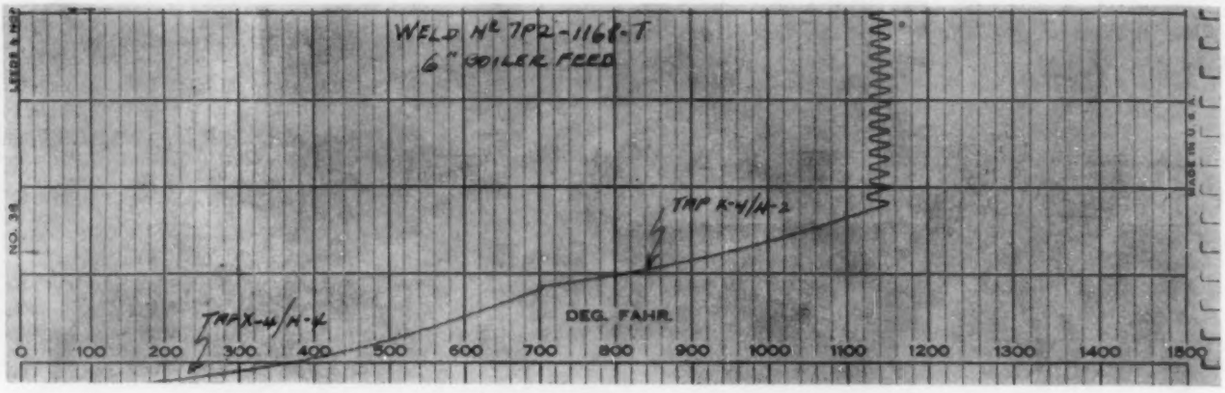


Fig. 2

for operation. One winding was used for two sizes of pipe by making a different insulating shield for each pipe size.

As stated previously the power supplied to the winding can be obtained from any 60-cycle power circuit of sufficient capacity but the voltage should be variable over a considerable range in comparatively small steps. In the first place, since both the ampere turns and the voltage per turn for unit current in the heater winding, increase with the pipe diameter, it is practically impossible to design heater windings for a wide range of pipe sizes all of which will operate at the same voltage. Furthermore, even for a given diameter of pipe and a given heater winding, the proper current and voltage depends upon such variable conditions as the wall thickness, the heat radiation from the pipe and the length of leads to and from the transformer. Moreover, even with these conditions maintained constant, the ampere turns required to reach a final temperature of 1100 to 1300° F. give a comparatively high initial rate of temperature rise, so that it is desirable to change the number of ampere turns during the heating cycle. The most convenient method of satisfying these requirements is to vary the applied voltage. As indicated in Fig. 1, this was accomplished by using a transformer with sufficient taps to give the required voltage steps. The transformer used was rated at 75 kva., 230 volts primary, with taps to give secondary voltages from 11 to 107 volts in 25 steps, each step giving a voltage about 10 per cent higher than the preceding one. This equipment can be used to stress-relieve welds in any pipes up to 16 in. in diameter. For larger pipes both more kva. and higher secondary voltages would be required.

Figure 1 also shows a magnetic contactor to energize the primary of the transformer and hence the heater winding. After the pipe has reached the required temperature, it is maintained within the desired limits by the operation of this contactor. This can be done by hand but it is much more satisfactory if the control is automatic. Therefore, a recording-controlling potentiometer operating from a thermocouple at the weld is used to control the operation of the magnetic contactor to maintain the temperature within the desired limits.

In order to make the auxiliary equipment readily available to the location where the welding is being done, the transformer, tap changer, contactor, line safety switch, control equipment and potentiometer are all mounted on a hand truck, with long primary and secondary leads.

During the short time The Detroit Edison Company has stress-relieved pipe welds by means of 60-cycle electric induction, both the method and the equipment developed have proved most satisfactory. Minor changes can undoubtedly be made in the equipment as further use shows up limitations, but it is believed that no major modifications will be necessary.

The weld temperature measured at any single point can be maintained within 20° F. of the desired temperature with automatic control. The maximum point-to-point variation in temperature which results from such conditions as differences in surface radiation, has been found to be approximately 50° F., for the larger sizes of pipes used, that is, 12 to 16 in. The variation is less for the smaller pipes. The precision in temperature control precludes any danger of changing the nature of the grain structure by exceeding the critical temperature of the metal. A typical stress-relief temperature record is shown in Fig. 2.

The points in favor of this method may be listed.

1. The equipment, though somewhat bulky for the larger pipes, can be used wherever there is sufficient clearance around the pipe to do a satisfactory welding job.

2. The time required to put the equipment in place ready for operation depends on local conditions but is moderate in all cases.

3. Power supply to the heater winding may be obtained from any 60-cycle circuit of sufficient capacity.

4. The energy required varies with the size of pipe but is small in any case. For instance, stress-relieving a weld in a 2½-in. pipe required 3 kw.-hrs., in an 8-in. pipe 13 kw.-hrs. and in a 16-in. pipe 27 kw.-hrs.

5. The method is far cleaner and produces much less waste heat than fuel-fired devices.

6. The method assures flexible, yet precise, heat control. The rate of heating may be varied at will, within reasonable limits.

Robbing "Efficiency" to Pay "Power Factor"

By R. L. BRIGGS†

IN RECENT issues of some of the magazines devoted to welding problems certain articles have emphasized the importance of the power factor at which resistance welders operate. While the subject of power factor was not given technical treatment, undue emphasis was given to its importance. Well informed electrical engineers, familiar with the problems involved in designing resistance welders, realize that other factors have equal importance and rate equal consideration. Such men might properly wonder why welder power factor should be favored at the expense of welder efficiency.

In fairness to the resistance welder industry, past and future purchasers of resistance welding equipment should know that machines manufactured by reputable organizations are designed and constructed with a sound appreciation for and scientific understanding of the relative importance of power factor. Efficiency, mechanical strength, a high production ability and machine utility are not sacrificed unnecessarily to give a welding machine a high power factor. The good designer strives for the best combination of all the important characteristics.

Fundamentals

(*A*) *Power Factor*

Fundamentally, the power factor is the ratio of the true power to the apparent power drawn by an electrical device. This might be written as p.f. $= \frac{W}{P}$. The apparent power P is measured in voltamperes, the product of the voltage across the terminals of the device and the current in amperes supplied to it. The true power W is measured in watts and is that portion of the apparent power which is converted from electrical into some other form of energy such as heat, light or mechanical work. In alternating current circuits the true power is less than the apparent power, in direct current circuits the two are equal.

If we make an analysis of the conditions producing the relationship between true and apparent power we can arrive at several other definitions of power factor.

1. If θ is the electrical angular displacement between the current and the voltage supplied to the welder then

$$\text{p.f.} = \cos\theta \qquad (1)$$

It can also be shown that if X is the reactance and R the effective A.C. resistance of the welder that

$$\text{Tan}\,\theta = \frac{X}{R} \qquad (2)$$

2. If Z is the impedance of the welder it can be demonstrated that

$$\text{p.f.} = \frac{R}{Z} \qquad (3)$$

† Research Engineer Thomson-Gibb Electric Welding Company.

(*B*) *Efficiency*

Efficiency is the ratio of the output to the input. In a resistance welder the output is the electrical energy expended in the form of heat to make the weld. This energy can be measured in watts. The input is the *true power* supplied to the welder, and is also measured in watts. Since the output equals the input minus the losses, the efficiency can be written

$$\text{Eff.} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Input} - \text{Losses}}{\text{Input}} \qquad (4)$$

If we let all the losses occurring in the copper be W_c and those in the iron be W_i then

$$\text{Eff.} = \frac{W - W_c - W_i}{W} \qquad (5)$$

(*C*) *The E.P.F. Factor*

Let us assume that a welding job requires an output of W_o watts. The input to the welder, by equation 4, must be

$$W = \frac{W_o}{\text{Eff.}}$$

From our fundamental definition of power factor it follows that the voltampere input P must be

$$P = \frac{W}{\text{p.f.}}$$

hence

$$P = \frac{W_o}{\text{Eff.} \times \text{p.f.}} \qquad (6)$$

We may write this equation as

$$W_o = P \times \text{Eff.} \times \text{p.f.}$$

This equation tells us that the ability of a resistance welder to make a weld (i.e., give an output of W_o) is measured by multiplying the apparent power drawn by the welder by a factor, this factor consisting of the *product of both the efficiency and the power factor*.

It is important that this relationship be clearly understood. It can be demonstrated by practical tests as well as sound theory. It explains why a welder with a power factor of 0.60 and an efficiency of 70% is a better welder than one with a power factor of 0.80 and an efficiency of 50%. The first machine has an E.P.F. factor (efficiency times power factor) of 0.42 while the E.P.F. factor of the second welder is only 0.40. If both machines have the same voltampere capacity, the first machine will give 5% more useful power for welding purposes despite the fact that it operates at 20% lower power factor.

Technical Discussion

(*A*) *The Resistance Welder*

In order to facilitate further discussion of the power factor and efficiency characteristics of welders it is neces-

sary that a description of the terms which will be employed be given.

Figure I shows a simplified sketch of a welder. When speaking of the transformer, we refer to the primary coils A, the secondary coil B and the core C. When speaking of the load on the transformer we refer to the leads D from the transformer to the stock to be welded, and the stock to be welded F. D_1 is the flexible lead necessary to allow motion of one side of the welding dies D_4. In a spot welder the leads D_2 are referred to as horns, and the distance G is called the throat length. The throat width is the distance H. When we refer to the complete welder circuit we mean the transformer and the complete load on it.

In butt and flash welders the welding point is much closer to the transformer than shown in the figure. The leads D_2 may be quite different in shape, and the lead D_5 may not be necessary. There still exists, however, a length and width to the load circuit. Sometimes, too, the transformer secondary B is made of flexible material which makes the lead D_1 unnecessary.

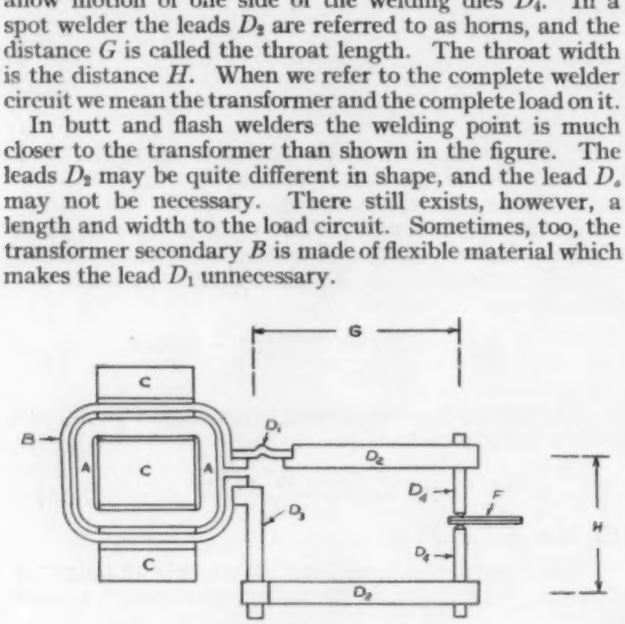


Fig. 1

(B) *The Power Factor*

Let us discuss the factors which influence power factor and methods of making the power factor better. As has been shown in equation 3, the power factor is given by the formula p.f. $= \frac{R}{Z}$. We may increase the power factor by either of two general methods:

1. We may increase the value of R.

This may be done by making the copper cross sections in the primary secondary of insufficient cross section or unefficient shape, by making poor contact in the contact surface between the various leads in the load circuit, or reflecting resistance into the load circuit through the presence of other metal close to the throat of the welder.

These methods are all objectionable. Using insufficient cross sections in the current conductors causes undue heating, as does inefficient shape of these conductors. Using poor contact in the contact surfaces occurring in the load circuit also results in local heating where proper cooling is difficult. Placing metal close to the welder throat is particularly ineffectual if the metal be iron or steel, since the effect is to build up Z faster than R, thus lowering the power factor.

Another objection which is quite fundamental is that when heating in the welder circuit occurs at any point other than in the stock to be welded, it means that energy is being lost and hence that the efficiency is being lowered. Also any increase in R also increases Z but not proportionally.

2. We may decrease the value of Z.

The impedance of the welder circuit is given as $Z = \sqrt{R^2 + X^2}$ where X is the equivalent reactance of the entire circuit. Obviously we should not attempt to decrease Z by decreasing R since this would actually decrease the power factor. So the only method left is to decrease X. This may be done in two ways:

(a) Decreasing the transformer reactance X_e.

Formulae for transformer reactance have been carefully worked out and show that: (1) it varies with the frequency of the alternating current; (2) it varies with the square of the primary turns; (3) it varies with the shape and number of the transformer coils; (4) it varies with the spacing between the coils; (5) it varies with the type of core used.

It is beyond the power of the welder designer to control frequency, and for a given type of welder he cannot vary the number of turns in the primary by any considerable amount. He can, however, cnotrol the shape of the coils, their spacing and to some extent the number of coils used. He can often, too, use a more correct type of core.

A study of design principles shows us that the finest possible arrangement would be: (a) the use of thin coils; (b) the use of many coils; (c) the enclosure of as much of the coils as possible with the core; (d) the placing of the primary and secondary coils in the same space. These features cannot be completely realized. The designer may, however, come as close to the ideal arrangement as is practical from a cost as well as physical point of view.

The objections to some of the procedures suggested above are: (a) the effective resistance is sometimes increased by changing the coil shape; (b) the manufacture of many thin coils is costly; (c) it is impossible to construct cheaply a core which wraps the transformer coils to a large extent.

(b) Decreasing the load reactance X_L.

The importance of this reactance may be better understood if it is realized that its effect on the input side of the welder circuit is increased by the square of the ratio of the primary to the secondary turns. In some welders this effect is so large that even if the welder contained a high power factor high efficiency transformer, the net effect is to give the welder a low efficiency and power factor.

This load reactance may be decreased by: (1) shortening the throat length; (2) by narrowing the throat width; (3) by keeping all iron or steel away from the throat. The first and second of these methods cannot always be used without interfering with the utility of the welder. The third method is often difficult without rendering the welder mechanically faulty and insufficiently strong.

(C) *The Efficiency*

Let us discuss the factors which influence efficiency and methods of making it higher. We learn from equation 5 that the efficiency is given as

$$\text{Eff.} = \frac{W - W_e - W_i}{W}$$

We may increase the value of the efficiency in two ways:

1. We may decrease the iron losses W_i.

This may be done by using sufficient cross section of iron in the transformer core C, by properly laminating this iron, and by using a suitable high quality transformer iron of low loss characteristics.

In actual practice the increase in efficiency obtained through attempting to further reduce the losses normally occurring in the present type of welding transformer is so slight as not to warrant the increase in costs which would result. This is due to the fact that the transformer iron losses are a small proportion of the total losses.

2. We may decrease the copper losses W_e.

This may be done by: (1) making the copper sections of sufficient cross section; (2) using copper of high conductivity; (3) making all contact surfaces of low resistance,

particularly in the load circuit; (4) using efficient conductor shapes to keep the eddy currents as low as possible; and (5) keeping all solid metal masses as far away from the leads and conductors as is practical and mechanically sound.

The objection to the first four methods suggested is that these improvements also reduce the power factor. The heating caused by eddy currents in the large copper sections necessary in a resistance welder is so large a proportion of the total losses that effort used to reduce this loss is effort well expended. To achieve this result, however, it is necessary that the designer have a sound technical knowledge of the principle involved in the production of the eddy currents and the mathematical ability to make the proper analyses.

It should be pointed out that too much refinement in this direction results in reducing the power factor to a serious extent. While it can be demonstrated that the highest point of efficiency is reached when $W_i = W_o$, in a resistance welder such a condition is practically impossible to obtain and if it were possible it would result in abnormally low power factors. The need for keeping the E.P.F. factor as high as possible, from a practical point of view, should be the aim of every resistance welder transformer designer.

(*D*) *Typical Example*

In order to demonstrate the application of the principles outlined in the preceding sections two welding circuits are analyzed. Each of their transformers has identical copper cross sections in primary and secondary, the same core cross sections, the same number of coils, the same number of primary turns, a single turn secondary, operates on the same line voltage, is connected to the same size of load circuit, and is designed for the same alternating current frequency. The two transformers differ physically only in the *shape* of the coils and core.

Comparison Table of Two Welding Circuits

	Welder "A"	Welder "B"
Kva. Input	21.47	27.49
Kw. Input	16.45	18.96
Power Factor	76.6%	68.9%
Kw. Output—Welding Power	4.32	7.08
Efficiency	26.25%	37.37%
Losses in Kw.—Total	12.36	13.06
Iron Loss	0.230	0.236
Primary Copper Loss	2.13	2.05
Secondary Copper Loss	9.80	10.45
Load Leads Copper Loss	0.20	0.324
% Due to Eddy Currents	91.2%	78.6%
Input Resistance	1.728 ohms	1.276 ohms
Input Reactance	1.448	1.214
Input Impedance	2.254	1.760
Voltage Regulation at Weld	319%	288%
E.P.F. Factor	0.1937	0.2579

A careful study of this table will show the advantages derived from careful design of the coil and core shape. Note particularly how the copper losses due to eddy currents, also the welder input impedance, were materially reduced by changing these shapes alone. Note, too, that transformer *B* is the superior transformer and has the higher E.P.F. factor despite its lower power factor.

Conclusion

The following table gives representative values of the E.P.F. factor for various throat sizes. These values should not be taken as invariable. They are presented as an illustration of the average values which will be found in the standard types of resistance welders. There will be a variation in the E.P.F. factor in welders of different classifications which have the same throat length and width. A seam welder, for example, will have a slightly higher factor than a spot welder. This is due to the fact that the seam welder must be designed to operate at a maximum duty cycle, while the spot welder does not have this characteristic since the spot welder designer must consider first cost as well as operating costs and hence omits this refinement. A 10% increase in the factor may be used for properly constructed seam welders.

E.P.F. Factor Versus Throat Size

Throat Length	Throat Width	E.P.F. Factor
4	3	0.28
10	4	0.22
16	5	0.17
22	6	0.15
12	6	0.20
18	6	0.14
24	6	0.12
18	10	0.125
18	12	0.11

As an illustration of the use of the tables, let us assume that we desire to weld steel stock. To make the usual type of spot weld on 16-gage stock, using $^1/_8$ second timing, we require 2.38 kw. To weld this on a spot welder having a throat length of 18 in. and width of 12 in. we would need 2.38 divided by 0.11 or 21.6 kva. The method of determining the power output required to weld different materials in the various types of welding will be presented in subsequent articles.

The users of resistance welding equipment should bear in mind that such apparatus as is offered to the trade will have varying characteristics. This machine may have a better appearance, that one a special type of transformer, and another type may boast of a high power factor. What the user of a resistance welder is expecting to find, however, is a reasonably economical performance commensurate with the first cost; and performance is certainly materially affected by the welding ability.

The important point to be remembered in discussing the relative welding ability of two welders drawing the same number of kva. from the power lines is that the welder with the higher E.P.F. factor (the value of the power factor multiplied by the efficiency) is the better welder. It will weld the same size of stock at less cost to the user, and less drain on the power lines. It should also be remembered that unless the E.P.F. factor is made larger there is no advantage in a high power factor welder to the user, there is no sense in robbing "Efficiency" to pay "Power Factor."

Pre-Construction Weld Testing

Proposed Methods of Reducing Costs without Sacrificing Safety*

By JAMES W. OWENS†

Introduction

General

1. The symposium, of which this paper is a part, is primarily concerned with the Qualification and Periodic Re-Qualification of Operators of Fusion Welding Equipment, and the expenses incurred therein. Therefore, the major portion of the paper will deal with these phases of Pre-Construction Weld Testing. On the other hand, the writer desires to call attention to the fact that the technical and commercial problems involved cannot be satisfactorily solved without a simultaneous consideration of such "Construction" and/or "Proof" Tests as should be required to insure the safety of fusion-welded products in general.

2. Another important point to be borne in mind is that no distinction can be made between the workmanship of a manual operator and of a machine operator, in so far as tests and test requirements are concerned, in view of the fact that the major variables of the manual and automatic fusion-welding processes are the same.

The Need of Weld Testing to Insure Safety

3. The necessity for Pre-Construction Weld Tests, Periodic Pre-Construction Weld Tests, Construction Weld Tests and for Proof Tests, in order to insure the safety of the product, has not been questioned by industry. The reason for this is that it is now generally recognized that these tests are *absolutely necessary for the control of the "human factor."* On the other hand, there have been some technical and/or cost objections to the *type of tests and test specimens*, the *number of test specimens* and to the *test requirements called for in some construction codes*. Furthermore, increasing costs, due to a *constant repetition* of identical or practically identical Pre-Construction Tests, have created a demand among manufacturers that steps be taken by the AMERICAN WELDING SOCIETY to consider the entire question of Weld Testing in the light of its present technical knowledge of fusion welding, and the experience of industry in the manufacture of practically every type of fusion-welded product.

4. As a result of the foregoing, the Board of Directors of the Society has appointed *two Committees* to work on the problem—the *first one* from the standpoint of *correlation of Code requirements for qualification of operators of welding equipment*, of which Mr. C. W. Obert of the Linde Air Products Company is Chairman; and the *second one to study feasibility of coordinating codes on welding* and of which Mr. Andrew Vogel of the General Electric Company is Chairman.

Major Factors Influencing the Cost of Pre-Construction Weld Testing

5. Basically, there are *two major factors* which affect the cost of Pre-Construction Weld Testing:

(*a*) The non-uniformity of the tests, test specimens and test requirements of the Fusion Welding Codes which have been issued by various technical societies, governmental, regulatory and other bodies.

(*b*) The fact that, *until very recently*, practically all Government Departments, Casualty Insurance Companies, regulatory and other bodies, regarded an in-

* Paper presented at the Fall Meeting A. W. S., New York, New York, October 1 to 5, 1934.

† Director, National Weld Testing Bureau, Pittsburgh, Pa., and Consulting Engineer, Pittsburgh Testing Laboratory, Pittsburgh, Pa.

Table 1—Proposed Forms and Sizes of Standard Pre-Construction Test Welds

Sizes of Welds Used in Construction	Required Sizes of Pre-Construction Test Welds (Butt Welds Only)	Test Numbers				
		*⅜ Fillet Welds	Double-Welded Butts		Single-Welded Butts	
			With Backing Strip	Without Backing Strip	*With Backing Strip	**Without Backing Strip
1/4" and less	Minimum Construction Weld, and 1/4"	02 F	02 D	02 WD	02 B	02 WB
From 1/4" to 5/8", inclusive	1/4" and 5/8"	25 F	25 D	25 WD	25 B	25 WB
5/8" and over	5/8" and 1"	58 F	58 D	58 WD	58 B	58 WB
From less than 1/4" to 5/8", inclusive	Minimum Construction Weld, 1/4" and 5/8"	05 F	05 D	05 WD	05 B	05 WB
All Sizes	Minimum Construction Weld, 1/4", 5/8" and 1"	08 F	08 D	08 WD	08 B	08 WB

Types of Product—* All products, but shall be the standard Pre-Construction Test Welds for buildings, bridges and other framed structures; machinery construction; boilers and unfired pressure vessels; and large-diameter tanks and pipe-lines.

** All products, but shall be the standard Pre-Construction Test Welds for those products wherein a backing strip is not used or seldom used, for example: pipe fittings, piping installations, pipe-lines, small-diameter low-pressure tanks, and for repairs to riveted boilers and unfired pressure vessels for unlimited service.

vestigation of a manufacturer's welding process (Process Approval), and Pre-Construction Tests of his operators (Qualification), as "inspection." As a logical result, these groups insisted on making their own independent pre-construction investigations in connection with all welded products and structures under their cognizance.

6. In considering the influence of the *first factor* and its effect on the cost of Pre-Construction Weld Testing, it should be borne in mind that on account of the number of variables involved in the production of sound welds, there is an *irreducible minimum* to the types and number of Pre-Construction, Construction and Proof Tests, which must be required if fusion welding is to secure and maintain the universal confidence of engineers, architects and users. While some reductions are possible, nevertheless, any approach to a solution of this problem should not unduly stress this phase, but concentrate on:

Securing *uniformity* of tests, test specimens and/or test requirements, among the various Codes, and for the three types of tests—Pre-Construction, Construction and Proof. A number of detail recommendations are given herein, which it is hoped will pave the way for a solution of this phase of the problem.

7. The *second factor*, as a problem, is largely commercial and its solution hinges on the issuance of reports by a neutral and disinterested body,* and of which there can be no question as to their authenticity and reliability. In this connection, the writer is pleased to report that, on this basis, a constant repetition of tests is now being avoided by industry with the assistance of the organization with which he is associated. Some of the practical details involved are:

(*a*) The strict adherence to Code requirements.

(*b*) The requirement that indicating and recording instruments used in a test are in good condition and calibration.

(*c*) The witnessing of the welding and the testing of the specimens.

(*d*) The identification of the operators who have complied with the requirements by means of a seal stamped photograph.

(*e*) The seal stamping of all reports and test specimens.

* See paper by author presented before the 1934 Convention of the International Acetylene Association entitled, "Commercial Methods of Testing Welds." Copies may be obtained from the Association—30 E. 42nd St., New York, N. Y.

Table 2—Proposed Minimum Number of Standard Test Specimens Required for Each Size of Pre-Construction Test Weld, and the Welding Positions Required for Various Types of Products

(For Weld Size, see Table 1)

Test No.	Welding Positions of Test Plates	Fillet Weld Test Specimens		Butt Weld Test Specimens					Types of Product
		Transverse Shear	*Fracture	Full Section Tension	Reduced Section Tension	Face Bend	Root Bend	*Nick-Break	
PC-1	Flat	2	1						*Pressure vessels, tanks, machinery and piping which is movable and axis horizontal
PC-2	Flat Vertical	1 2	1						Buildings, bridges and other framed structures
PC-3	Flat Vertical Overhead	1 1 2	1						*Ship hulls
PC-4	Flat Vertical Overhead **Inclined-overhead	1 1 1 2	1						*Piping which is fixed and axis at any angle
PC-5	Flat			1	1	1	1	1	*Pressure vessels, tanks, machinery and piping which is movable and axis horizontal
PC-6	Flat Vertical			1	1 1	1	1	1	Buildings, bridges and other framed structures
PC-7	Flat Vertical Overhead			1	1 1 1	1	1	1	*Ship hulls
PC-8	Flat Vertical Overhead **Inclined-overhead			1	1 1 1 1	1	1	1	*Piping which is fixed and axis horizontal, or not exceeding 45° to the horizontal
PC-9	Flat Vertical Overhead ***Inclined-horizontal			1	1 1 1 1	1	1	1	*Piping which is fixed and axis vertical, or less than 45° to the vertical
PC-10	Flat Vertical Overhead ***Inclined-horizontal **Inclined-overhead			1	1 1 1 1 1	1	1	1	*Piping which is fixed and axis at any angle and repairs to boilers, and pressure vessels for unlimited service

* Fracture and Nick-Break Tests shall *only* be required for products wherein tightness is a major factor, and for products subject to dynamic and fatigue stresses.

** Linear direction of weld inclined at an angle of 45° to the horizontal, weld being made from the underside of the parts being welded.

*** Parts welded inclined at an angle of 45° to the horizontal, linear direction of weld horizontal, weld being made from the underside of the parts being welded.

Fundamental Recommendations for Simplifying, Coordinating and Standardizing Weld Tests

Recommendations

8. That the two Committees referred to be authorized by the Society to immediately prepare a comprehensive and basic "A. W. S. Weld Testing Code for Fusion-Welded Products."**

9. That this Code be made up of three parts and an Appendix as follows:

Part 1. Pre-Construction Weld Testing Code.
Part 2. Construction Weld Testing Code.
Part 3. Proof Testing Code.

Appendix:

Section 1. Code enforcement.
Section 2. (Loose Leaf) List of names of all bodies accepting the A. W. S. Weld Testing Code.
Section 3. (Loose Leaf) List of all Special Tests and Special Test Requirements which have been incorporated in the various Construction Codes issued by the bodies accepting the A. W. S. Weld Testing Code.

10. That the A. W. S. Filler Metal Specification Committee be authorized by the Society to coordinate its activities with the work of the above Committees preparing the A. W. S. Weld Testing Code.

11. That all references to "Classes of Welding" or "Classes of Products" be eliminated from the Code.

12. That the Code, and the tests as given therein, shall be applicable to *all* types of weldable carbon-steel products, wherein the carbon content of the base metal does not exceed 0.35%, and wherein ultimate strengths are within the range of —55,000 to 70,000 lb. per sq. in. Furthermore, that the Code and Tests shall be applicable to ingot and wrought-iron products, although these materials are of lower tensile strengths.

13. That, on the completion of this Code, the Society should take steps to have it, not only accepted by *all* bodies sponsoring Fusion Welding Codes, but incorporated in the Codes issued by these bodies and by the Society.

14. That, in all Fusion Welding Construction Codes, the A. W. S. Weld Testing Code should be referred to by name, and all of its tests should be referred to by number. For example, A. W. S. Pre-Construction Qualification Tests Nos. O8F-PC1 and O8B-PC5.

15. That the "Test Numbers" shall clearly indicate the major variables involved, as shown in Tables 1 and 2.

Detail Recommendations for the Proposed A. W. S. Pre-Construction Weld Testing Code

Base Metal

16. That the chemical and physical properties of the base metal of the Pre-Construction Test Specimens shall fall within the limits of the base metal of the products specified in the Construction Code of the product.

17. That, in order to make it possible for the Pre-Construction Tests of fillet and butt welds to be applicable to *all* types of products, plate material shall be used instead of pipe material, for the test specimens of pipe welds.

Forms and Sizes of Welds

18. That the forms and sizes of welds shown in Table 1, in relation to construction welds, shall be the standard for Pre-Construction Tests of all types of products.

19. That, provided the Pre-Construction Test Requirements have been complied with for a given form of butt weld listed in Table 1, it shall not be necessary to make tests for any other form or forms of butt welds listed to its left. For example, if the test requirements of Test No. O8WB (single welded butt without a backing strip) have been complied with, it will not be necessary to make Tests Nos. O8B, O8WD and/or O8D.

Welding Positions, Tests and Test Specimens

20. That the minimum number of Test Specimens for each size of Pre-Construction Test Weld and the welding positions required for various types of products, shall be as shown in Table 2. In this connection, it will be noticed that an additional welding position is added to each succeeding fillet-weld test, and to each succeeding butt-weld test. With this arrangement, therefore, and provided all other fundamental conditions have been complied with, an operator who has complied with the requirements for Test No. PC-4 would also be qualified to make fillet welds on all types of products listed under Tests Nos. PC-3, PC-2 and PC-1.

Similarly an operator who has complied with the requirements for Test No. PC-8 would also be qualified to make butt welds on all types of products listed under Tests Nos. PC-7, PC-6 and PC-5.

21. That, as quantitative Pre-Construction and Construction Tests, the Fracture and Nick-Break Tests shall only be required for:

(*a*) Products wherein the highest quality of weld metal is essential, e.g., boilers and unfired pressure vessles; and/or for:

(*b*) Products wherein tightness is essential, e.g., pipe fittings and piping installations.

22. That comparative photographs of weld metal fractures shall be embodied in the A. W. S. Weld Testing Code—these photographs to serve the same purpose as the exographs in the A. S. M. E. Boiler Code.

Welding Positions, Tests and Test Specimens

23. That the *Full Section Tension Test* for butt welds be restricted to a Pre-Construction Test, and that its reinforcement be retained. The primary object of this test would be a determination of the tensile strength of the base metal used in the test.

24. That the shape of the *Reduced Section Tension Specimen* be modified to more effectively concentrate the stress in the weld. The shape recommended is that shown in Part "D" of the A. W. S. Marine Code which has recently been approved by the Marine Committee of the Society.

25. That, when a bend specimen is tested with the face of the weld in tension, the specimen shall be known as a *Face Bend Test Specimen;* and when tested with the root of the weld in tension, the specimen shall be known as a *Root Bend Test Specimen.*

26. That, when a Bend Test is required, both Face Bend and Root Bend Tests shall be made. It is this basic requirement, wherein root penetration is always investigated in a butt weld, that makes it possible to reduce costs by eliminating tests as outlined in paragraph 19.

Concluding Remarks and Recommendations

27. As specifically pointed out in the text, there is an irreducible minimum number of Pre-Construction Test Specimens, which must be made to insure safety. It is believed that this minimum number has been obtained by the methods proposed and summarized in Tables 1 and 2. These tables are so arranged that the minimum number of test specimens for any given set of conditions can easily be determined. Furthermore, the method of numbering the tests provides a convenient and a very

**The preparation of this Code has been authorized.

definite means of recording the major variables involved in a test.

28. For certain types of products, this reduction in the number of Pre-Construction Test Specimens is only obtained by an increase in the number and type of Construction and Proof Tests. This change from present practice should not be objectionable from a cost standpoint, as the additional Construction and Proof Tests would only be made when products are actually constructed. For example:

(*a*) Provision should be made for Construction Tests for so-called A. S. M. E. Class 2 Products. These Tests should be similar to those now required for Class 1 Products.

(*b*) Provision should be made for statically stress-relieving so-called Class 2 Products, and the hammer-shock testing of the joints wherein the base metal of the product is stressed beyond the yield point.

29. It is recommended that the following tests be considered as *Standard Construction Tests*—Transverse Shear, Reduced Section Tension, Face Bend, Root Bend, All-Weld Metal, Fracture and Nick-Break.

30. It is further recommended that the following tests be considered as *Special Construction Tests*—Photomacrographs, Photomicrographs, Chemical Analyses of Weld Metal and Fusion Zones, Impact and Impact-Tension.

WELDING SOCIETY ACTIVITIES AND RELATED EVENTS

ANNUAL MEETING

This year the Annual Meeting of the AMERICAN WELDING SOCIETY will be devoted to a one-day business session, committee meetings and a meeting of the Board of Directors.

PROGRAM
SIXTEENTH ANNUAL MEETING
of the
AMERICAN WELDING SOCIETY
APRIL 25, 1935
HOTEL PENNSYLVANIA

Thursday, April 25th

Morning

REGISTRATION

11:00 A.M. Business Session—President D. S. Jacobus, Presiding.

PROGRAM

Report on Society Activities by President Jacobus.
Tellers' Report on Election of Officers.
Other Business—Discussion.

Afternoon

2:00 P.M. Meeting American Bureau of Welding—C. A. Adams, Director, Presiding.

PROGRAM

Discussion of the future work and organization of the American Bureau of Welding.

Evening

6:30 P.M. Meeting Board of Directors—D. S. Jacobus, Presiding.

PROGRAM

Review of Society activities.
Unfinished business.
Introduction of new President.
Appointment of Officers and Committees.
Plans for coming year.

OBITUARY

Louis H. Burkhart

Louis H. Burkhart, for the past thirty-eight years Chief Engineer of Struthers-Wells Company, Warren, Pa., died at St. Francis Hospital, Pittsburgh, March 5th. He was a graduate of the University of Missouri, a member of the American Society of Mechanical Engineers, and a member of the AMERICAN WELDING SOCIETY with which he served on the Code Conference Committee. Mr. Burkhart was a pioneer in the development and application of gas and electric welding to steel plate construction and special machinery, as well as the application and use of the modern metals and alloys in welded construction. He was a Director of the company he served, a Director of the Warren National Bank and the Warren Y. M.-C. A. He was actively interested in civic affairs and gave freely of his time and means to every worthy cause. He was sixty-six years of age.

Machine Tool Builders' Exposition

The Machine Tool Builders' Exposition will be held in Cleveland, September 11–21st, inclusive, at the Cleveland Auditorium.

Metal Industries Exhibition

The Metal Industries Exhibition will be held at Osaka, Japan, May 10 to 31, 1935. All nations are invited to take part. The Industries Exhibition is the largest in Japan and business organizations or industrialists desiring to take part should get in touch with the AGNE publication.

Welding Symposium British Iron and Steel Institute

Arrangements have been made by this organization for printing the papers of the Symposium under five groups. Price set for papers of each group 75¢; complete set of advance copies at $2.75. A remittance of $7.50 if sent before May 3rd will secure a complete set of advance papers and the two bound volumes of the papers to be printed after the conference.

United States Civil Service Examinations

The United States Civil Service Commission has announced open competitive examinations as follows:

Chemists

Applications for the positions of chemist, and senior, associate and assistant chemists must be on file with the U. S. Civil Service Commission at Washington, D. C., not later than April 8, 1935.

The entrance salaries range from $2600 to $4600 a year, less a 3½ per cent retirement deduction.

Junior Physicist

Applications for the position of junior physicist must be on file with the U. S. Civil Service Commission at Washington, D. C., not later than April 8, 1935.

The entrance salary is $2000 a year, subject to a deduction of 3½ per cent toward a retirement annuity.

Assistant Naval Architect

Optional subjects are: electricity, heat, mechanics and optics.

Applications for the position of Assistant Naval Architect must be on file with the U. S. Civil Service Commission at Washington, D. C., not later than April 1, 1935.

Optional branches are: ship piping and ventilation, hull structures and arrangements, scientific ship calculations, and general.

The entrance salary is $2600 a year, subject to a deduction of 3½ per cent toward a retirement annuity.

Appropriate education and experience are required.

Full information may be obtained from the Secretary of the United States Civil Service Board of Examiners at the post-office or customhouse in any city which has a post-office of the first or the second class, or from the United States Civil Service Commission, Washington, D. C.

Boiler and Hull Inspectors

Applications for the positions of local and assistant inspectors of boilers, and local and assistant inspectors of hulls, Bureau of Navigation and Steamboat Inspection, must be on file with the U. S. Civil Service Commission, Washington, D. C., not later than April 15, 1935.

The entrance salaries for local inspectors are $3200 a year, and for assistant inspectors, $2900 a year. These salaries are subject to a deduction of 3½ per cent toward a retirement annuity.

Applicants must have had specified experience.

World's Largest Plate Mill

A very interesting pamphlet elaborately prepared with illustrations has recently been published by the Lukens Steel Company summarizing the work of this Company in this field.

SECTION ACTIVITIES

BOSTON

The next meeting of the Boston Section will be held Friday evening, March 22nd, at 7:30 P.M. at the plant of the Austin Hastings Co., 226 Binney St., Cambridge. An interesting program arranged and sponsored by the Westinghouse Electric & Manufacturing Co. is to be presented. The program is as follows:

Subject: "A.C. Arc Welding."
Speaker: W. B. Strathdee, Westinghouse Elec. & Mfg. Co.

Subject: "Welding from the Metallurgical Viewpoint."
Speaker: J. P. Walsted, Materials Engineers, Bethlehem Shipbuilding Corp.

Demonstrations of: "A.C. arc-welding equipment; Welding of non-ferrous metals and special alloys.

Sound film: "The House of Tomorrow."

CHICAGO

A joint meeting with the American Society of Mechanical Engineers, Chicago Section, was held in the Auditorium of the Engineering Building on February 22nd. Dr. D. S. Jacobus, President of the AMERICAN WELDING SOCIETY and Past-President of the American Society of Mechanical Engineers, gave a very interesting talk on "The Old and the New in Fusion Welding," and showed illustrations pertaining to the welding of steam boilers and other types of pressure vessels and some of the interesting work at Boulder Dam.

CLEVELAND

The Cleveland Section held their regular monthly meeting February 13th in the Cleveland Engineering Society with approximately 140 present. There were two speakers for the evening and both talks were illustrated by interesting slides. Dr. D. S. Jacobus spoke on "Advances in the Use of Fusion Welding," and Mr. W. S. Walker, Welding Engineer of The Linde Air Products Company presented a paper on "Flame Cutting Curved Penstock Plates for Boulder Dam."

DETROIT

Joint meeting of the AMERICAN WELDING SOCIETY and American Society for Metals was held February 11th at the Fort Shelby Hotel, Detroit. The dinner preceding the meeting was attended by 150 members and guests and 250 attended the technical sessions. There was one section devoted to non-ferrous metals, which was presided over by H. M. St. John. At this session Mr. S. Tarkus, Manager Newark, New Jersey Plant, Federated Metals Corporation, presented a paper on "Soft Soldering." The ferrous section was presided over by R. P. Bailey, Chairman Detroit Section. At this session R. E. Kinkead, Consulting Welding Engineer presented a general talk with particular reference to stress relieving. A "coffee talk" by Dr. Henry A. Luce, Speaker of the House of Delegates of the Michigan State Medical Society, followed the dinner on the "Relation of Socialized Medicine to Industry."

LOS ANGELES

At a regular meeting of the Los Angeles Section the following officers were elected:

Chairman: Frank Howard, Smith Emery Company.
Vice-Chairman: Jim Blake, Victor Equipment Company.
Secretary: Charles E. DeLong, Air Reduction Sales Co.
Executive Committee: Frank Longo, Southern Pacific Co.; Oliver G. Bowen, Structural Eng.; R. W. Binder, McClintic Marshal Co.; Wayne Howard, General Petroleum Co.; A. P. Johnson, Johnson Stainless Steel Rods; James W. McCarthy, Frank Wiggins Trade School.

After the election those present at the meeting were taken to the Douglas Aircraft Factory and were escorted through this plant by very capable guides and allowed to see just how these modern planes are manufactured and assembled.

NEW YORK

The New York Section had a very interesting meeting on the evening of March 12th in the Engineering Societies Building which was devoted to "Ship Welding." Samuel S. Scott, Chairman of the Section, presided at the Meeting.

Lieut.-Commander John D. Crecca, who had been actively engaged in the design, building and inspection of naval ships since 1919, and is at present on duty as Superintending Constructor, New York, in connection with the design and inspection of three classes of destroyers, presented a general picture of the status of the various phases of welding on naval vessels and in Navy Yards. His paper included a brief historical review of welding as used on naval vessels for repairs, alterations and new construction. It covered the scope of welding, processes used, personnel control, materials used, plant equipment, design features and the influence on production.

J. L. Wilson, Assistant Chief Surveyor, American Bureau of Shipping, covered briefly the American Bureau of Shipping's attitude in the development of welding for ship construction. His talk included mention of the Bureau's regulations and specifications, its requirements for testing of electrodes and welders, and a description of some examples of ship welding, together with a general review of what has been accomplished to date.

PHILADELPHIA

The regular monthly meeting of this Section was held on February 18th, with about 100 present. Mr. Harry W. Pierce of the New York Shipbuilding Co. gave a very interesting talk on "Control of Welding in Shipyards." After his paper there was a discussion, led by Mr. T. M. Jackson.

The subject of "Stress Analysis" will be taken up at the March 18th meeting.

PITTSBURGH

The February meeting of the Pittsburgh Section was held on the 20th in the Fort Pitt Hotel. Mr. R. F. Helmkamp, of the Applied Engineering Department, Air Reduction Sales Co., presented a paper on the "Advances in Machine Construction by Gas Welding and Cutting." Paper covered the fabrication of some heavy mechanical presses recently completed which combined the use of steel plate and castings. About fifty slides were used to illustrate the method of procedure. A general discussion of the subject was presented, following the presentation of the paper.

The next regular meeting of this Section will be a joint meeting with the Mechanical Section of the Engineers Society of Western Pennsylvania and the Pittsburgh Section of the American Society of Mechanical Engineers, to be held in the William Penn Hotel, March 20th. Mr. M. B. Butler, Jr., of the Hi-Tensile Department of the Edward G. Budd Manufacturing Co., will present a paper entitled "The Development of a New Industry," which will cover the "Shot-welding of Stainless Steel," particularly from the construction angle. The paper will be illustrated with moving picture films and slides.

EMPLOYMENT SERVICE BULLETIN

POSITIONS VACANT

V-58. Wanted Shop Superintendent, Steel plate fabricator capable of layout some knowledge of welding. State experience past five years, references and salary expected.

V-59. Wanted Acetylene Welder. Heavy bronze welding, sheet aluminum, pipe welding and general experience. State experience past five years, references and hour rate expected.

V-60. Wanted Arc Welder. Heavy coated electrodes, stainless steel and pressure tanks. State experience past five years, references and hour rate expected.